

ANSI/MC96.1-1982
(Revision of ANSI-MC96.1-1975)

American National Standard

Temperature
Measurement
Thermocouples



Instrument Society of America

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AMERICAN NATIONAL STANDARD

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FOREWORD

(This Foreword is included for information purposes and is not part of ANSI MC96.1)

The development of this American National Standard has resulted from the work of the American National Standards Committee on Temperature Measurement, MC96. The Committee was organized in 1946 under the sponsorship of the Instrument Society of America, the scope of the Committee being designated as follows:

Requirements for temperature measurement thermocouples, including terminology, fabrication, wire sizes, installation, color codes of thermocouple and thermocouple extension wire, Temperature-EMF tables and tolerances have been coordinated with the International Electrotechnical Commission (IEC).

Credit must be given to the National Bureau of Standards and to Committee E20 on Temperature Measurement of the American Society for Testing and Materials for the development of the temperature-EMF tables and for recommendations as to the maximum recommended temperature of the various materials. Special credit must also be given to G. W. Burns, NBS-Washington, D.C., and Dr. Robert Powell, formerly with NBS-Boulder, for providing the thermocouple reference tables.

This Standard has been prepared as a part of the service of the Instrument Society of America toward a goal of uniformity in the field of instrumentation. To be of real value this document should not be static, but should be subjected to periodic review. Toward this end the Society welcomes all comments and criticisms, and asks that they be addressed to the Standards and Practices Board Secretary, Instrument Society of America, P.O. Box 12277, Research Triangle Park, N.C. 27709.

In 1821, Seebeck discovered that, in a closed circuit made up of wires of two dissimilar metals, electric current will flow if the temperature of one junction is elevated above that of the other. In 1886, Le Chatelier introduced a thermocouple consisting of one wire of platinum and the other of 90 percent platinum-10 percent rhodium. This combination, Type S, is still the international standard for purposes of calibration and comparison, and defines the International Practical Temperature Scale of 1968 from the antimony to the gold point. This type of thermocouple was made and sold by W. C. Heraeus, GmbH of Hanau, Germany, and is sometimes called the Heraeus Couple. Somewhat later, it was learned that a thermoelement composed of 87 percent platinum and 13 percent rhodium, Type R, would give a somewhat higher EMF output. This type is frequently used in industry. In 1954 a thermocouple was introduced in Germany whose positive leg is an alloy of platinum and 30 percent rhodium. Its negative leg is also an alloy of platinum and 6 percent rhodium. This combination, Type B, gives somewhat greater physical strength and greater stability, and can withstand somewhat higher temperature than types R and S.

In an effort to find less costly metals for use in thermocouples, a number of combinations were tried. Iron and

nickel were useful and inexpensive. Pure nickel, however, becomes very brittle upon oxidation; and it was learned that an alloy of about 55 percent copper, 45 percent nickel originally known as constantan would eliminate this problem. This alloy combination, iron-constantan, has since been widely used and is designated Type J. The present calibration for Type J was established by the National Bureau of Standards (see NBS Monograph 125).

In an effort to find a couple useful to higher temperatures than the iron versus copper-nickel combination, a 90 percent nickel-10 percent chromium alloy as a positive wire, and a 95 percent nickel-5 percent aluminum, manganese, silicon alloy as a negative wire was developed. This combination (originally called Chromel-Alumel) is known as Type K. Similar alloys for specific applications have since become available, to the same curve.

Another combination, copper versus copper-nickel, Type T, is used particularly at below-zero temperatures. The temperature-EMF Reference Table was prepared by the National Bureau of Standards in 1938 and revised in NBS Monograph 125.

The Type E Thermocouple, 90 percent nickel-10 percent chromium versus copper-nickel, is receiving increasing attention and use where corrosion of small diameter iron wire is a problem and a higher EMF output is desirable.

Further information on the letter designated type thermocouples is given in Appendix C.

Several combinations using tungsten, rhenium and their binary alloys are widely used at high temperatures in inert or reducing atmospheres, and are nearing acceptance as standard.

For additional information on temperature measurement thermocouples, reference may be made to NBS Special Publication 300, Volume II, "Precision Measurement and Calibration-Temperature," 1968 and to NBS Monographs 124 and 125, published by United States Department of Commerce, National Bureau of Standards. Specific attention is called to the reference categories on Thermoelectric Theory and Calibration, and Thermoelectric Devices. Additional information is in STP-470B, "Manual on the Use of Thermocouples," 1981, published by the American Society for Testing and Materials.

For many years, letter designations have been assigned by ANSI Committee MC96 and endorsed by international standards as a device to identify certain common types without using proprietary trade names, and to associate them with temperature-emf relationships established by the National Bureau of Standards. Color codes for the insulation of letter-designated wires are also assigned by MC96 to facilitate identification in the field. The assignment of a letter designation and/or color code by MC96 constitutes an acknowledgment of an existing recognition by NBS of a defining temperature-emf relationship and an existing general usage, and does not

constitute an endorsement of the thermocouple type by ISA, ANSI, and NBS. The letter designation applies only to the temperature-emf relationship and not to the material. Other material, having different temperature-emf relationships, may well be equivalent or superior in some applications.

The use of the letter X to indicate thermocouple extension wire appeared obvious. The use of the term lead wire, or compensating lead wire, is to be discouraged because it frequently is confused with the term lead (element).

Much discussion was involved in the use of the color red to designate polarity, since red is used popularly in electrical circuits to indicate positive. No nationally-accepted code known to the committee covered this point. Research into manufacturers' records showed that, in thermocouple circuits, the red negative had been in use for more than forty years.

The colors used to designate the various compositions and combination of thermocouple and extension wire were originally selected upon an almost arbitrary basis. Colors which had been used by large manufacturers

were given very careful consideration and comparison so that as few changes as possible would be required to establish uniformity. Millions of miles of wire with these color codes are presently in use.

In ANSI-MC96.1 thermocouple and thermocouple extension wires are designated by letters. This has been done primarily to eliminate the use of proprietary names. The designations are given in Table 1 of the text.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards. The Department is further aware of the benefits to USA users of ISA Standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end this Department will endeavor to introduce SI and SI-acceptable metric units as optional alternatives to English units in all new and revised standards to the greatest extent possible. The ASTM "Metric Practice Guide," endorsed and published as National Bureau of Standards Handbook 102 and as ANSI Z210.1, is the reference guide for definitions, symbols, abbreviations and conversion factors.

1. CODING OF THERMOCOUPLE WIRE AND EXTENSION WIRES

This standard applies to thermocouples and extension wires.

Its purpose is to establish uniformity in the designation of thermocouples and extension wires and to provide,

by means of the color of its insulation, an identification of its type or composition as well as its polarity when used as part of a thermocouple system.

TABLE 1
THERMOCOUPLE TYPE LETTER DESIGNATIONS

| Type | Nominal Temperature Range | Temperature-EMF Relationship Data | Material Identification* (Positive Material in Caps)** |
|------|---------------------------|-----------------------------------|---|
| B | 0 to 1820°C | Refer to Table 11 | PLATINUM-30 PERCENT RHODIUM versus platinum-6 percent rhodium |
| E | -270 to 1000°C | Refer to Table 12 | NICKEL-10 PERCENT CHROMIUM† versus copper-nickel |
| J | -210 to 760°C | Refer to Table 13 | IRON versus copper-nickel |
| K | -270 to 1372°C | Refer to Table 14 | NICKEL-10 PERCENT CHROMIUM † versus nickel-5 percent (aluminum, silicon) ‡‡ |
| R | -50 to 1768°C | Refer to Table 15 | PLATINUM-13 PERCENT RHODIUM versus platinum |
| S | -50 to 1768°C | Refer to Table 16 | PLATINUM-10 PERCENT RHODIUM versus platinum |
| T | -270 to 400°C | Refer to Table 17 | COPPER versus copper-nickel |

* Any combination of thermocouple materials having EMF-temperature relationships within the tolerances for any of the above-mentioned tables shall bear that table's appropriate type letter designation.

** The indicated polarity of the thermocouple materials applies for conditions when the measuring junction is at higher temperatures than the reference junction.

† It should not be assumed that thermoelements used with more than one thermocouple type are interchangeable or have the same millivolt limits of error.

‡‡ Silicon, or aluminum and silicon may be present in combination with other elements.

| TABLE 2 SYMBOLS FOR TYPES OF THERMOCOUPLE WIRE | | |
|--|----------|----------|
| Thermoelements | | |
| Type* | Positive | Negative |
| B | BP | BN |
| E | EP | EN |
| J | JP | JN |
| K | KP | KN |
| R | RP | RN |
| S | SP | SN |
| T | TP | TN |

* Any thermocouple material having temperature-EMF relationships within the tolerances for any of the above-mentioned tables shall bear that table's appropriate "type-letter" designation. Identification of some typical materials is contained in Appendix C (Table C-1).

| TABLE 3 SYMBOLS FOR TYPES OF EXTENSION WIRE | | | |
|--|-------------|----------|----------|
| Type | Combination | Positive | Negative |
| B | BX** | BPX | BNX |
| E | EX | EPX | ENX |
| J | JX | JPX | JNX |
| K | KX | KPX | KNX |
| R or S | SX* | SPX | SNX |
| T | TX | TPX | TNX |

* Both Type R or S Thermocouples use the same SX compensating extension wire.

** Special compensating extension wires are not required for reference junction temperatures up to 100°C. Generally copper conductors are used. However, proprietary alloys may be obtained for use at higher reference junction temperatures.

NOTE: Identification of some typical materials is contained in Appendix C (Table C-3).

TABLE 4
COLOR CODE - DUPLEX INSULATED THERMOCOUPLE WIRE

| Thermocouple | | | Color of Insulation | | |
|--------------|----------|----------|---------------------|-----------|----------|
| Type | Positive | Negative | Overall* | Positive* | Negative |
| E | EP | EN | Brown | Purple | Red |
| J | JP | JN | Brown | White | Red |
| K | KP | KN | Brown | Yellow | Red |
| T | TP | TN | Brown | Blue | Red |

* A tracer color of the positive wire code color may be used in the overall braid.

TABLE 5
COLOR CODE - SINGLE CONDUCTOR INSULATED THERMOCOUPLE EXTENSION WIRE

| Extension Wire Type | | | Color of Insulation | |
|---------------------|----------|----------|---------------------|------------------|
| Type | Positive | Negative | Positive | Negative* |
| B | BPX | BNX | Gray | Red-Gray Trace |
| E | EPX | ENX | Purple | Red-Purple Trace |
| J | JPX | JNX | White | Red-White Trace |
| K | KPX | KNX | Yellow | Red-Yellow Trace |
| R or S | SPX | SNX | Black | Red-Black Trace |
| T | TPX | TNX | Blue | Red-Blue Trace |

* The color identified as a trace may be applied as a tracer, braid, or by any other readily identifiable means.

NOTE OF CAUTION: In the procurement of random lengths of single conductor insulated extension wire, it must be recognized that such wire is commercially combined in matching pairs to conform to established temperature-EMF curves. Therefore, it is imperative that all single conductor insulated extension wire be procured in pairs, at the same time, and from the same source.

TABLE 6
COLOR CODE - DUPLEX INSULATED THERMOCOUPLE EXTENSION WIRE

| Extension Wire Type | | | Color of Insulation | | |
|---------------------|----------|----------|---------------------|----------|-----------|
| Type | Positive | Negative | Overall | Positive | Negative* |
| B | BPX | BNX | Gray | Gray | Red |
| E | EPX | ENX | Purple | Purple | Red |
| J | JPX | JNX | Black | White | Red |
| K | KPX | KNX | Yellow | Yellow | Red |
| R or S | SPX | SNX | Green | Black | Red |
| T | TPX | TNX | Blue | Blue | Red |

* A tracer having the color corresponding to the positive wire code color may be used on the negative wire color code.

2. TERMINOLOGY, WIRE SIZE, UPPER TEMPERATURE LIMIT, AND INITIAL CALIBRATION TOLERANCE FOR THERMOCOUPLES AND EXTENSION WIRE

2.1 Scope and Purpose

This section applies to thermocouples and extension wire.

This section establishes terminology, symbols, normal wire size, recommended upper temperature limit, and tolerance for thermocouples and extension wire.

2.2 Terminology and Symbols

2.2.1 Thermoelement

A thermoelement is one of the two dissimilar electrical conductors comprising a thermocouple.

2.2.2 Thermocouple

A thermocouple is two dissimilar thermoelements so joined as to produce a thermal emf when the measuring and reference junctions are at different temperatures.

1. *Measuring Junction.* The measuring junction is that junction of a thermocouple which is subjected to the temperature to be measured.
2. *Reference Junction.* The reference junction is that junction of a thermocouple which is at a known temperature or which is automatically compensated for its temperature.

NOTE: In normal industry practice the thermocouple element is terminated at the connection head. However, the Reference Junction is not ordinarily located in the connection head but is transferred to the instrument by the use of thermocouple extension wire.

2.2.3 Extension Wire

Extension wire is a pair of wires having such temperature-emf characteristics relative to the thermocouple with which the wires are intended to be used that, when properly connected to the thermocouple, the reference junction is transferred to the other end of the wires.

NOTE: Extension wires which are basically different in chemical composition from the thermocouple wires with which they are to be used are sometimes referred to as compensating extension wire. In this context, type SX and BX wires would be compensating extension wire and types TX, JX, EX, and KX wires would be extension wire.

2.2.4 Tolerances

The tolerance of a thermocouple or extension wire is the maximum allowable deviation in degrees from the standard emf-temperature values for the type of thermocouple in question when the reference junction temperature is at the ice point and the measuring junction is at the temperature to be measured.

2.2.5 Thermocouple Element

A thermocouple element is a pair of bare or insulated thermoelements joined at one end to form a measuring junction and intended for use as a thermocouple or as a part of a thermocouple assembly. (See Figure 1.)

The thermocouple element length is the overall length of the thermocouple element and is assigned the symbol A.

The thermocouple element diameter is the maximum transverse dimension of the insulated portion of the thermocouple element and is assigned the symbol Y.

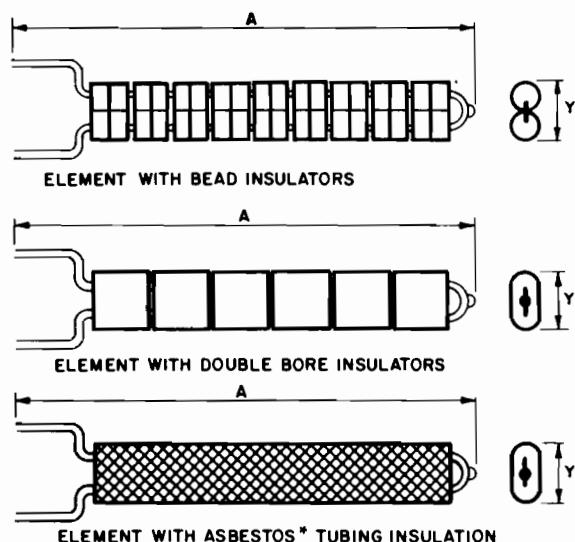


Figure 1. Thermocouple Elements

2.2.6 Thermocouple Assembly

A thermocouple assembly is an assembly consisting of a thermocouple element and one or more associated parts such as terminal block, connection head, and protecting tube.

1. *Terminal Block.* A terminal block is a block of insulating material that is used to support and join the terminations of conductors. (See Figure 2.)

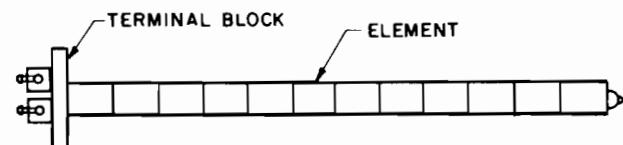


Figure 2. Thermocouple Element with Terminal Block

2. *Connection Head.* A connection head is a housing enclosing a terminal block for an electrical temperature sensing device and usually provided with threaded openings for attachment to a protecting tube and for attachment of conduit. (See Figures 3 and 4.)

*Asbestos is being replaced with safer high-temperature materials.

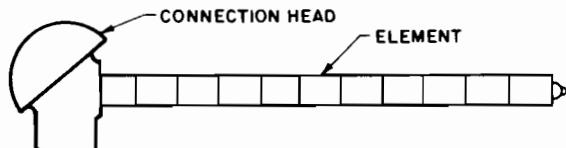


Figure 3. Thermocouple Element with Connection Head

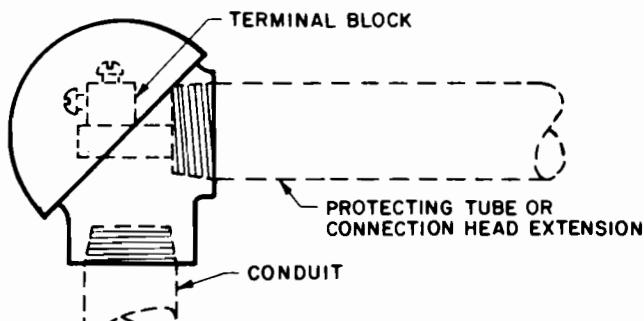


Figure 4. Connection Head

3. *Connection Head Extension.* A connection head extension is a threaded fitting or an assembly of fittings extending between the thermowell or angle fitting and the connection head.

The connection head extension length is the overall length of the connection head extension and is assigned the symbol N. (See Figure 11.)

4. *Protecting Tube.* A protecting tube is a tube designed to enclose a temperature sensing device and protect it from the deleterious effects of the environment. It may provide for attachment to a connection head but is not primarily designed for pressure-tight attachment to a vessel. A bushing or flange may be provided for the attachment of a protecting tube to a vessel. (See Figures 5, 6, 7, and 8.)

The protecting tube length is the overall length of a protecting tube and is assigned the symbol P. (See Figure 5.)

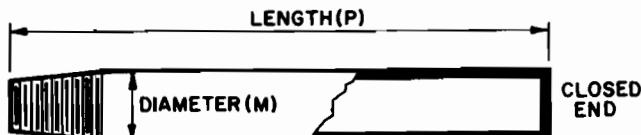


Figure 5. Protecting Tube

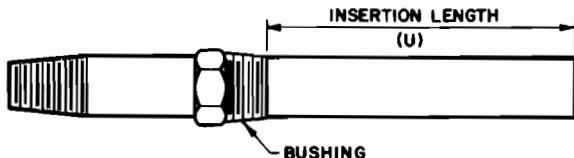


Figure 6. Protecting Tube with Mounting Bushing

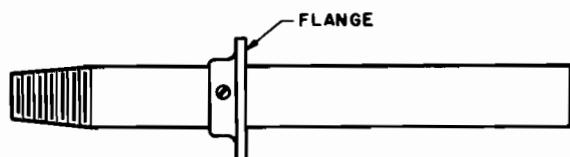


Figure 7. Protecting Tube with Mounting Flange

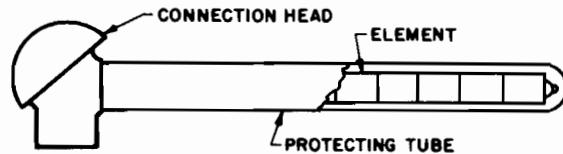


Figure 8. Thermocouple Element with Protecting Tube and Connection Head

The protecting tube diameter is the outside diameter of a protecting tube and is assigned the symbol M.

A protecting tube has one end closed unless it is specified as open end. (See Figure 9.)

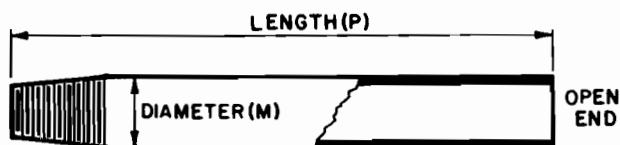


Figure 9. Open End Protecting Tube

5. *Thermowell.* A thermowell is a pressure-tight receptacle adapted to receive a temperature sensing element and provided with external threads or other means for pressure-tight attachment to a vessel.

A lagging extension is that portion of a thermowell above the threads, intended to extend through the lagging of a vessel. The lagging extension length is the length from the lower end of the external threads of the well to the outer end of the portion intended to extend through the lagging of a vessel, less one inch allowance for threads, and is assigned the symbol T. (See Figure 10.)

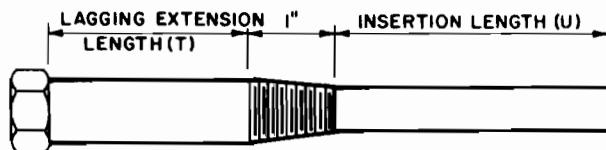


Figure 10. Well

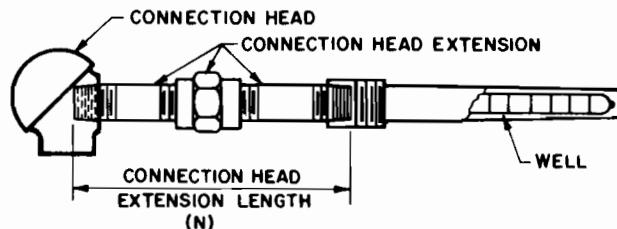


Figure 11. Thermocouple Assembly with Thermowell

The immersion length of a thermowell, protecting tube, or thermocouple element is the length from the free end to the point of immersion in the medium which is being measured and is assigned the symbol R. (See Figure 12.)

The insertion length of a thermowell, protecting tube or thermocouple element is the length from the free

end to, but not including, the external threads or other means of attachment to a vessel and is assigned the symbol U. (See Figures 10 and 12.)

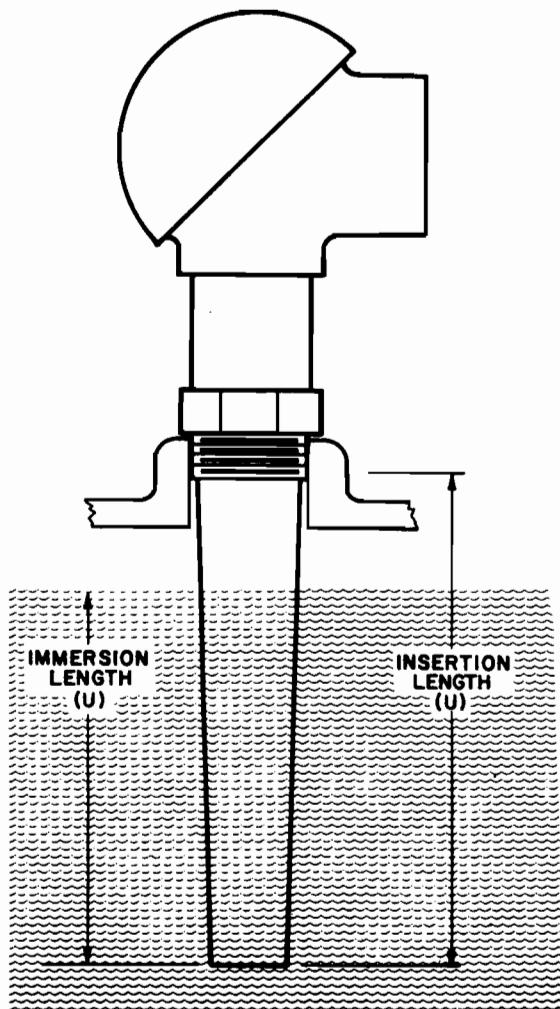


Figure 12. Immersion and Insertion Lengths for Thermocouple Assembly with Thermowell

2.2.7 Angle Type Thermocouple Assembly

An angle type thermocouple assembly is an assembly consisting of a thermocouple element, a protecting tube, an angle fitting, a connection head extension, and a connection head.

2.2.8 Other Forms of Thermocouples and Thermocouple Elements

1. **Coaxial Thermocouple Element.** A coaxial thermocouple element consists of a thermoelement in wire form within a thermoelement in tube form and electrically insulated from the tube except at the measuring junction.
2. **Sheathed Thermocouple.** A sheathed thermocouple is a thermocouple having its thermoelements, and sometimes its measuring junction, embedded in mineral oxide insulation compacted within a metal protecting tube.

SYMBOLS

| | Symbols |
|----------------------------------|---------|
| Thermocouple element length | A |
| Thermocouple element diameter | Y |
| Connection head extension length | N |
| Protecting tube length | P |
| Protecting tube diameter | M |
| Lagging extension length | T |
| Immersion length | R |
| Insertion length | U |

2.3 WIRE SIZES

2.3.1 Thermocouples

The wire sizes normally used for non-sheathed thermocouples are as follows:

For J, K, and E: 8, 14, 20, 24 and 28 AWG*

For T: 14, 20, 24, and 28 AWG*

For R, S and B: 24 AWG* only

2.3.2 Extension wires

The wire sizes normally used for extension wire, either singly or in pairs, are 14, 16, and 20 AWG*. Sixteen (16) gage is most commonly used. Twenty (20) gage and smaller may be used when bundled and reinforced to provide strength for pulling. These sizes apply to all types of extension wires.

2.4 UPPER TEMPERATURE LIMITS

Table 7 gives the recommended upper temperature limits for the various thermocouples and wire sizes. These limits apply to protected thermocouples in conventional closed-end protecting tubes. They do not apply to sheathed thermocouples having compacted mineral oxide insulation.

In any general recommendation of thermocouple temperature limits, it is not practical to take into account special cases. In actual operation, there may be instances where the temperature limits recommended can be exceeded. Likewise, there may be applications where satisfactory life will not be obtained at the recommended temperature limits. However, in general, the temperature limits listed are such as to provide satisfactory thermocouple life when the wires are operated continuously at these temperatures. Various factors affecting thermocouple life are discussed in Appendix C.

* American Wire Gage, also known as B&S (Brown & Sharpe)

2.5 TOLERANCE OF INITIAL CALIBRATION

Table 8, 9 and 10 give the standard and special tolerance of initial calibration for thermocouples and thermocouple extension wires. The tolerance of initial calibration is defined as the allowable deviation of the thermocouple and extension wire in its initial condition as supplied by the manufacturer from the standard emf-temperature tables. Once the thermocouple is in use its calibration will change. The magnitude and direction of the change are dependent on temperature, time and environmental conditions affecting the thermocouple and may not be accurately predicted. The tolerances for each type of thermocouple apply only over the temperature range for which the wire size in question is recommended (see Table 7). These tolerances

should be applied only to standard wire sizes. The same tolerances may not be obtainable in special sizes. These tolerances do not include installation or system errors. See Appendix C, paragraph C4.1 for the thermocouple installations and errors.

Where tolerances are given in percent, in Table 8, the percentage applies to the temperature being measured. For example, the standard tolerance of Type J over the temperature range 277° to 760°C is $\pm 3/4$ percent. If the temperature being measured is 538°C, the tolerance is $\pm 3/4$ percent of 538, or $\pm 4.0^\circ\text{C}$. To determine the tolerance in degrees Fahrenheit, multiply the tolerance in degrees Celsius times 1.8.

TABLE 7
RECOMMENDED UPPER TEMPERATURE LIMITS FOR PROTECTED
THERMOCOUPLES. UPPER TEMPERATURE LIMIT FOR VARIOUS
WIRE SIZES (AWG), deg C

| Thermocouple Type | No. 8 Gage | No. 14 Gage | No. 20 Gage | No. 24 Gage | No. 28 Gage |
|-------------------|------------|-------------|-------------|-------------|-------------|
| B | | | | 1700 | |
| E | 870 | 650 | 540 | 430 | 430 |
| J | 760 | 590 | 480 | 370 | 370 |
| K | 1260 | 1090 | 980 | 870 | 870 |
| R & S | | | | 1480 | |
| T | | 370 | 260 | 200 | 200 |

TABLE 8
INITIAL CALIBRATION TOLERANCES FOR THERMOCOUPLES
Reference Junction 0°C

| Thermocouple Type | Temperature Range, °C | TOLERANCES | |
|-------------------|-----------------------|---|--|
| | | Standard (whichever is greater) | Special (whichever is greater) |
| B | 870 to 1700 | $\pm 0.5\%$ | |
| E | 0 to 900 | $\pm 1.7^\circ\text{C}$ or $\pm 0.5\%$ | $\pm 1^\circ\text{C}$ or $\pm 0.4\%$ |
| J | 0 to 750 | $\pm 2.2^\circ\text{C}$ or $\pm 0.75\%$ | $\pm 1.1^\circ\text{C}$ or $\pm 0.4\%$ |
| K | 0 to 1250 | $\pm 2.2^\circ\text{C}$ or $\pm 0.75\%$ | $\pm 1.1^\circ\text{C}$ or $\pm 0.4\%$ |
| R or S | 0 to 1450 | $\pm 1.5^\circ\text{C}$ or $\pm 0.25\%$ | $\pm 0.6^\circ\text{C}$ or $\pm 0.1\%$ |
| T | 0 to 350 | $\pm 1^\circ\text{C}$ or $\pm 0.75\%$ | $\pm 0.5^\circ\text{C}$ or $\pm 0.4\%$ |
| Cryogenic Ranges | | | |
| E* | -200 to 0 | $\pm 1.7^\circ\text{C}$ or $\pm 1\%$ | ** |
| K* | -200 to 0 | $\pm 2.2^\circ\text{C}$ or $\pm 2\%$ | ** |
| T* | -200 to 0 | $\pm 1^\circ\text{C}$ or $\pm 1.5\%$ | ** |

* Thermocouples and thermocouple material are normally supplied to meet the tolerances specified in the table for the normal specified range. The same materials, however, may not fall within the cryogenic tolerances in the second section of the table. If materials are required to meet the cryogenic tolerances, the purchase order must so state. Selection of materials usually will be required. Tolerances indicated in this table are not necessarily an indication of the accuracy of temperature measurements in use after initial heating of the materials.

** Little information is available to justify establishing special tolerances for cryogenic temperatures. Limited experience suggests the following tolerances for types E and T thermocouples:

Type E -200 to 0°C $\pm 1^\circ\text{C}$ or $\pm 0.5\%$ (whichever is greater)

Type T -200 to 0°C $\pm 0.5^\circ\text{C}$ or $\pm 0.8\%$ (whichever is greater)

These tolerances are given only as guide for discussion between purchaser and supplier. Due to the characteristics of the materials, cryogenic tolerances for Type J thermocouples and special cryogenic tolerances for Type K thermocouples are not listed.

TABLE 9
INITIAL CALIBRATION TOLERANCES FOR
THERMOCOUPLE EXTENSION WIRES

Reference Junction 0°C

| Extension Wire Type | Temperature Range, °C | Tolerances | |
|---------------------|-----------------------|------------|---------|
| | | Standard | Special |
| EX | 0 to 200°C | ±1.7°C | - |
| JX | 0 to 200°C | ±2.2°C | ±1.1°C |
| KX | 0 to 200°C | ±2.2°C | - |
| TX | 0 to 100°C | ±1.0°C | ±0.5°C |

3. NON-CERAMIC INSULATION OF THERMOCOUPLE AND EXTENSION WIRES

The normal function of thermocouple and extension wire insulation is to provide electrical insulation. If this function is not provided or is compromised in any way, the indicated temperature may be in error. Insulation of this type (non-ceramic) may be affected adversely by moisture, abrasion, flexing, temperature extremes, chemical attack, and nuclear radiation. Each type of insulation has its own limitations. A knowledge of these limitations is essential if accurate and reliable measurements are to be made.

A number of coatings are presently available commercially. The strong points as well as limitations are discussed in ASTM Special Technical Publication STP-470B, "Manual on the Use of Thermocouples in Temperature Measurement."

In summary, this type of insulation should be selected only after considering possible exposure temperatures and heating rates, the number of temperature cycles, mechanical movement, moisture, routing of the insulated wire, and chemical deterioration.

TABLE 10
INITIAL CALIBRATION TOLERANCES FOR
THERMOCOUPLE COMPENSATING EXTENSION WIRE

Reference Junction 0°C

| Thermocouple Type | Compensating Wire Type | Temperature Range, °C | Tolerances |
|-------------------|------------------------|-----------------------|--|
| B | BX*** | 0 to 100 | $\left\{ \begin{array}{l} +0.000 \text{ mV } (+0^\circ\text{C}^*) \\ -0.033 \text{ mV } (-3.7^\circ\text{C}^*) \end{array} \right\}$ |
| R, S | SX** | 0 to 200 | ±.057 mV (±5°C*) |

* Due to the non-linearity of the Types, R, S, and B temperature-emf curves, the error introduced into a thermocouple system by the compensating wire will be variable when expressed in degrees. The degree C tolerances given in parentheses are based on the following measuring junction temperatures:

| Type Wire | Measuring Junction Temperature |
|-----------|--------------------------------|
| BX | Greater than 1000°C |
| SX | Greater than 870°C |

** Copper (+) versus copper nickel alloy (-).

***Copper versus copper compensating extension wire, usable to 100°C with maximum errors as indicated, but with no significant error over 0 to 50°C range. Matched proprietary alloy compensating wire is available for use over the range 0 to 200°C with claimed tolerances of ±0.033 mV. (±3.7°C*)

4. TEMPERATURE-EMF TABLES FOR THERMOCOUPLES

4.1 Scope and Purpose

This section applies to the temperature-emf relationships of materials used for temperature measurement thermocouples.

Its purpose is to provide reference tables of temperature-amf values for Type B,E,J,K,R,S, and T thermocouples, in a form convenient for industrial and laboratory use.

4.2 Introduction

The values in these tables are based upon the International Practical Temperature Scale of 1968 (IPTS-68) and the U.S. legal electrical units. All the data in Tables 11 to 17 have been extracted from "Thermocouple Reference Tables Based on the IPTS-68," National Bureau of Standards Monograph 125. These tables differ slightly from previous tables for the following reasons: improved measurements and data analysis techniques, slight changes in commercial thermocouple materials, and also changes in the temperature scale and electrical units. The significance of these factors, as well as the origin of each of the tables, is discussed in the NBS reference noted above, and it should be consulted for details.

These tables give values of EMF to three decimal places (0.001 mV) for one degree Celsius ($^{\circ}\text{C}$) temperature intervals. If greater precision is required, the NBS reference noted above should be consulted. It includes tables giving values of EMF to four decimal places (0.0001 mV) and analytical functions for each thermocouple type that allow a direct and precise calculation of the EMF-temperature relationship.

Tables for each type of thermocouple giving values of EMF as a function of temperature in degrees Fahrenheit ($^{\circ}\text{F}$) can be found in ANSI/ASTM Standard E230, "Temperature-Electromotive Force (EMF) Tables for Thermocouples." Tables giving EMF-temperature values (in both $^{\circ}\text{C}$ and $^{\circ}\text{F}$) for single-leg thermoelements referenced to platinum (NBS Pt-67) are also given in the above ANSI/ASTM standard.

4.3 Use of Temperature-EMF Tables

These Temperature-EMF reference tables serve two very useful purposes in that they provide a means for converting the generated EMF of certain thermocouple material combinations into equivalent temperatures, and they enable the calibration and checking of thermocouples and thermocouple extension wire.

If the reference junction is maintained at 0°C , the appropriate temperature or EMF data may be read directly from the tables. When it is not practical to maintain the reference junction temperature at 0°C , these tables may still be used by applying an appropriate correction. The value of the correction may be obtained from these tables. An example to illustrate how to obtain and apply this correction follows.

Let us suppose a Type J thermocouple was used in an installation to determine the temperature of a fluid medium and an EMF output of 18.070 mV was observed. Also, a mercury thermometer in close proximity to the thermocouple reference junction produced a reading of 20°C .

To use the Type J Table to obtain a value for the temperature of the fluid medium, the observed EMF output of the thermocouple must first be corrected to compensate for the difference between the reference junction temperature actually used and 0°C . The correction is the EMF value given by the Type J Table at the reference junction temperature actually used (20°C). As shown below, this EMF value (1.019 mV) is algebraically added to the observed EMF output to obtain the value of EMF that the thermocouple would produce if the reference junction were at 0°C .

| | |
|---|----------|
| Observed Type J Thermocouple Output: | 18.070mV |
| Correction Factor (Table value at reference temperature actually used) for reference junction at 20°C : | 1.019mV |
| Corrected Output: | 19.089mV |

The corrected output of 19.089 mV is then used to determine from the Type J Table the equivalent temperature value of 350°C .

TABLE 11

TEMPERATURE-EMF FOR TYPE B THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 0 | 0.000 | -0.000 | -0.000 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.002 | -0.002 | -0.002 | 0 |
| 10 | -0.002 | -0.002 | -0.002 | -0.002 | -0.002 | -0.002 | -0.002 | -0.002 | -0.003 | -0.003 | -0.003 | 10 |
| 20 | -0.003 | -0.003 | -0.003 | -0.003 | -0.003 | -0.002 | -0.002 | -0.002 | -0.002 | -0.002 | -0.002 | 20 |
| 30 | -0.002 | -0.002 | -0.002 | -0.002 | -0.002 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.000 | 30 |
| 40 | -0.000 | -0.000 | -0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 40 |
| 50 | 0.002 | 0.003 | 0.003 | 0.003 | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 | 0.006 | 0.006 | 50 |
| 60 | 0.006 | 0.007 | 0.007 | 0.008 | 0.008 | 0.009 | 0.009 | 0.010 | 0.010 | 0.011 | 0.011 | 60 |
| 70 | 0.011 | 0.012 | 0.012 | 0.013 | 0.014 | 0.014 | 0.015 | 0.015 | 0.016 | 0.017 | 0.017 | 70 |
| 80 | 0.017 | 0.018 | 0.019 | 0.020 | 0.020 | 0.021 | 0.022 | 0.022 | 0.023 | 0.024 | 0.025 | 80 |
| 90 | 0.025 | 0.026 | 0.026 | 0.027 | 0.028 | 0.029 | 0.030 | 0.031 | 0.031 | 0.032 | 0.033 | 90 |
| 100 | 0.033 | 0.034 | 0.035 | 0.036 | 0.037 | 0.038 | 0.039 | 0.040 | 0.041 | 0.042 | 0.043 | 100 |
| 110 | 0.043 | 0.044 | 0.045 | 0.046 | 0.047 | 0.048 | 0.049 | 0.050 | 0.051 | 0.052 | 0.053 | 110 |
| 120 | 0.053 | 0.055 | 0.056 | 0.057 | 0.058 | 0.059 | 0.060 | 0.062 | 0.063 | 0.064 | 0.065 | 120 |
| 130 | 0.065 | 0.066 | 0.068 | 0.069 | 0.070 | 0.071 | 0.073 | 0.074 | 0.075 | 0.077 | 0.078 | 130 |
| 140 | 0.078 | 0.079 | 0.081 | 0.082 | 0.083 | 0.085 | 0.086 | 0.088 | 0.089 | 0.091 | 0.092 | 140 |
| 150 | 0.092 | 0.093 | 0.095 | 0.096 | 0.098 | 0.099 | 0.101 | 0.102 | 0.104 | 0.106 | 0.107 | 150 |
| 160 | 0.107 | 0.109 | 0.110 | 0.112 | 0.113 | 0.115 | 0.117 | 0.118 | 0.120 | 0.122 | 0.123 | 160 |
| 170 | 0.123 | 0.125 | 0.127 | 0.128 | 0.130 | 0.132 | 0.133 | 0.135 | 0.137 | 0.139 | 0.140 | 170 |
| 180 | 0.140 | 0.142 | 0.144 | 0.146 | 0.148 | 0.149 | 0.151 | 0.153 | 0.155 | 0.157 | 0.159 | 180 |
| 190 | 0.159 | 0.161 | 0.163 | 0.164 | 0.166 | 0.168 | 0.170 | 0.172 | 0.174 | 0.176 | 0.178 | 190 |
| 200 | 0.178 | 0.180 | 0.182 | 0.184 | 0.186 | 0.188 | 0.190 | 0.192 | 0.194 | 0.197 | 0.199 | 200 |
| 210 | 0.199 | 0.201 | 0.203 | 0.205 | 0.207 | 0.209 | 0.211 | 0.214 | 0.216 | 0.218 | 0.220 | 210 |
| 220 | 0.220 | 0.222 | 0.225 | 0.227 | 0.229 | 0.231 | 0.234 | 0.236 | 0.238 | 0.240 | 0.243 | 220 |
| 230 | 0.243 | 0.245 | 0.247 | 0.250 | 0.252 | 0.254 | 0.257 | 0.259 | 0.262 | 0.264 | 0.266 | 230 |
| 240 | 0.266 | 0.269 | 0.271 | 0.274 | 0.276 | 0.279 | 0.281 | 0.284 | 0.286 | 0.289 | 0.291 | 240 |
| 250 | 0.291 | 0.294 | 0.296 | 0.299 | 0.301 | 0.304 | 0.307 | 0.309 | 0.312 | 0.314 | 0.317 | 250 |
| 260 | 0.317 | 0.320 | 0.322 | 0.325 | 0.328 | 0.330 | 0.333 | 0.336 | 0.338 | 0.341 | 0.344 | 260 |
| 270 | 0.344 | 0.347 | 0.349 | 0.352 | 0.355 | 0.358 | 0.360 | 0.363 | 0.366 | 0.369 | 0.372 | 270 |
| 280 | 0.372 | 0.375 | 0.377 | 0.380 | 0.383 | 0.386 | 0.389 | 0.392 | 0.395 | 0.398 | 0.401 | 280 |
| 290 | 0.401 | 0.404 | 0.406 | 0.409 | 0.412 | 0.415 | 0.418 | 0.421 | 0.424 | 0.427 | 0.431 | 290 |
| 300 | 0.431 | 0.434 | 0.437 | 0.440 | 0.443 | 0.446 | 0.449 | 0.452 | 0.455 | 0.458 | 0.462 | 300 |
| 310 | 0.462 | 0.465 | 0.468 | 0.471 | 0.474 | 0.477 | 0.481 | 0.484 | 0.487 | 0.490 | 0.494 | 310 |
| 320 | 0.494 | 0.497 | 0.500 | 0.503 | 0.507 | 0.510 | 0.513 | 0.517 | 0.520 | 0.523 | 0.527 | 320 |
| 330 | 0.527 | 0.530 | 0.533 | 0.537 | 0.540 | 0.544 | 0.547 | 0.550 | 0.554 | 0.557 | 0.561 | 330 |
| 340 | 0.561 | 0.564 | 0.568 | 0.571 | 0.575 | 0.578 | 0.582 | 0.585 | 0.589 | 0.592 | 0.596 | 340 |
| 350 | 0.596 | 0.599 | 0.603 | 0.606 | 0.610 | 0.614 | 0.617 | 0.621 | 0.625 | 0.628 | 0.632 | 350 |
| 360 | 0.632 | 0.636 | 0.639 | 0.643 | 0.647 | 0.650 | 0.654 | 0.658 | 0.661 | 0.665 | 0.669 | 360 |
| 370 | 0.669 | 0.673 | 0.677 | 0.680 | 0.684 | 0.688 | 0.692 | 0.696 | 0.699 | 0.703 | 0.707 | 370 |
| 380 | 0.707 | 0.711 | 0.715 | 0.719 | 0.723 | 0.727 | 0.730 | 0.734 | 0.738 | 0.742 | 0.746 | 380 |
| 390 | 0.746 | 0.750 | 0.754 | 0.758 | 0.762 | 0.766 | 0.770 | 0.774 | 0.778 | 0.782 | 0.786 | 390 |
| 400 | 0.786 | 0.790 | 0.794 | 0.799 | 0.803 | 0.807 | 0.811 | 0.815 | 0.819 | 0.823 | 0.827 | 400 |
| 410 | 0.827 | 0.832 | 0.836 | 0.840 | 0.844 | 0.848 | 0.853 | 0.857 | 0.861 | 0.865 | 0.870 | 410 |
| 420 | 0.870 | 0.874 | 0.878 | 0.882 | 0.887 | 0.891 | 0.895 | 0.900 | 0.904 | 0.908 | 0.913 | 420 |
| 430 | 0.913 | 0.917 | 0.921 | 0.926 | 0.930 | 0.935 | 0.939 | 0.943 | 0.948 | 0.952 | 0.957 | 430 |
| 440 | 0.957 | 0.961 | 0.966 | 0.970 | 0.975 | 0.979 | 0.984 | 0.988 | 0.993 | 0.997 | 1.002 | 440 |
| 450 | 1.002 | 1.006 | 1.011 | 1.015 | 1.020 | 1.025 | 1.029 | 1.034 | 1.039 | 1.043 | 1.048 | 450 |
| 460 | 1.048 | 1.052 | 1.057 | 1.062 | 1.066 | 1.071 | 1.076 | 1.081 | 1.085 | 1.090 | 1.095 | 460 |
| 470 | 1.095 | 1.100 | 1.104 | 1.109 | 1.114 | 1.119 | 1.123 | 1.128 | 1.133 | 1.138 | 1.143 | 470 |
| 480 | 1.143 | 1.148 | 1.152 | 1.157 | 1.162 | 1.167 | 1.172 | 1.177 | 1.182 | 1.187 | 1.192 | 480 |
| 490 | 1.192 | 1.197 | 1.202 | 1.206 | 1.211 | 1.216 | 1.221 | 1.226 | 1.231 | 1.236 | 1.241 | 490 |
| 500 | 1.241 | 1.246 | 1.257 | 1.262 | 1.267 | 1.272 | 1.277 | 1.282 | 1.287 | 1.292 | 1.297 | 500 |
| 510 | 1.292 | 1.297 | 1.303 | 1.308 | 1.313 | 1.318 | 1.323 | 1.328 | 1.334 | 1.339 | 1.344 | 510 |
| 520 | 1.344 | 1.349 | 1.354 | 1.360 | 1.365 | 1.370 | 1.375 | 1.381 | 1.386 | 1.391 | 1.397 | 520 |
| 530 | 1.397 | 1.402 | 1.407 | 1.413 | 1.418 | 1.423 | 1.429 | 1.434 | 1.439 | 1.445 | 1.450 | 530 |
| 540 | 1.450 | 1.456 | 1.461 | 1.467 | 1.472 | 1.477 | 1.483 | 1.488 | 1.494 | 1.499 | 1.505 | 540 |
| 550 | 1.505 | 1.510 | 1.516 | 1.521 | 1.527 | 1.532 | 1.538 | 1.544 | 1.549 | 1.555 | 1.560 | 550 |
| 560 | 1.560 | 1.566 | 1.571 | 1.577 | 1.583 | 1.588 | 1.594 | 1.600 | 1.605 | 1.611 | 1.617 | 560 |
| 570 | 1.617 | 1.622 | 1.628 | 1.634 | 1.639 | 1.645 | 1.651 | 1.657 | 1.662 | 1.668 | 1.674 | 570 |
| 580 | 1.674 | 1.680 | 1.685 | 1.691 | 1.697 | 1.703 | 1.709 | 1.715 | 1.720 | 1.726 | 1.732 | 580 |
| 590 | 1.732 | 1.738 | 1.744 | 1.750 | 1.756 | 1.762 | 1.767 | 1.773 | 1.779 | 1.785 | 1.791 | 590 |
| 600 | 1.791 | 1.797 | 1.803 | 1.809 | 1.815 | 1.821 | 1.827 | 1.833 | 1.839 | 1.845 | 1.851 | 600 |
| 610 | 1.851 | 1.857 | 1.863 | 1.869 | 1.875 | 1.882 | 1.888 | 1.894 | 1.900 | 1.906 | 1.912 | 610 |
| 620 | 1.912 | 1.918 | 1.924 | 1.931 | 1.937 | 1.943 | 1.949 | 1.955 | 1.961 | 1.968 | 1.974 | 620 |
| 630 | 1.974 | 1.980 | 1.986 | 1.993 | 1.999 | 2.005 | 2.011 | 2.018 | 2.024 | 2.030 | 2.036 | 630 |
| 640 | 2.036 | 2.043 | 2.049 | 2.055 | 2.062 | 2.068 | 2.074 | 2.081 | 2.087 | 2.094 | 2.100 | 640 |

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|-------|---|---|---|---|---|---|---|---|---|---|----|-------|
|-------|---|---|---|---|---|---|---|---|---|---|----|-------|

TABLE 11 (Continued)

TEMPERATURE-EMF FOR TYPE B THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 650 | 2.100 | 2.106 | 2.113 | 2.119 | 2.126 | 2.132 | 2.139 | 2.145 | 2.151 | 2.158 | 2.164 | 650 |
| 660 | 2.164 | 2.171 | 2.177 | 2.184 | 2.190 | 2.197 | 2.203 | 2.210 | 2.216 | 2.223 | 2.230 | 660 |
| 670 | 2.230 | 2.236 | 2.243 | 2.249 | 2.256 | 2.263 | 2.269 | 2.276 | 2.282 | 2.289 | 2.296 | 670 |
| 680 | 2.296 | 2.302 | 2.309 | 2.316 | 2.322 | 2.329 | 2.336 | 2.343 | 2.349 | 2.356 | 2.363 | 680 |
| 690 | 2.363 | 2.369 | 2.376 | 2.383 | 2.390 | 2.396 | 2.403 | 2.410 | 2.417 | 2.424 | 2.430 | 690 |
| 700 | 2.430 | 2.437 | 2.444 | 2.451 | 2.458 | 2.465 | 2.472 | 2.478 | 2.485 | 2.492 | 2.499 | 700 |
| 710 | 2.499 | 2.506 | 2.513 | 2.520 | 2.527 | 2.534 | 2.541 | 2.548 | 2.555 | 2.562 | 2.569 | 710 |
| 720 | 2.569 | 2.576 | 2.583 | 2.590 | 2.597 | 2.604 | 2.611 | 2.618 | 2.625 | 2.632 | 2.639 | 720 |
| 730 | 2.639 | 2.646 | 2.653 | 2.660 | 2.667 | 2.674 | 2.682 | 2.689 | 2.696 | 2.703 | 2.710 | 730 |
| 740 | 2.710 | 2.717 | 2.724 | 2.732 | 2.739 | 2.746 | 2.753 | 2.760 | 2.768 | 2.775 | 2.782 | 740 |
| 750 | 2.782 | 2.789 | 2.797 | 2.804 | 2.811 | 2.818 | 2.826 | 2.833 | 2.840 | 2.848 | 2.855 | 750 |
| 760 | 2.855 | 2.862 | 2.869 | 2.877 | 2.884 | 2.892 | 2.899 | 2.906 | 2.914 | 2.921 | 2.928 | 760 |
| 770 | 2.928 | 2.936 | 2.943 | 2.951 | 2.958 | 2.966 | 2.973 | 2.980 | 2.988 | 2.995 | 3.003 | 770 |
| 780 | 3.003 | 3.010 | 3.018 | 3.025 | 3.033 | 3.040 | 3.048 | 3.055 | 3.063 | 3.070 | 3.078 | 780 |
| 790 | 3.078 | 3.086 | 3.093 | 3.101 | 3.108 | 3.116 | 3.124 | 3.131 | 3.139 | 3.146 | 3.154 | 790 |
| 800 | 3.154 | 3.162 | 3.169 | 3.177 | 3.185 | 3.192 | 3.200 | 3.208 | 3.215 | 3.223 | 3.231 | 800 |
| 810 | 3.231 | 3.239 | 3.246 | 3.254 | 3.262 | 3.269 | 3.277 | 3.285 | 3.293 | 3.301 | 3.308 | 810 |
| 820 | 3.308 | 3.316 | 3.324 | 3.332 | 3.340 | 3.347 | 3.355 | 3.363 | 3.371 | 3.379 | 3.387 | 820 |
| 830 | 3.387 | 3.395 | 3.402 | 3.410 | 3.418 | 3.426 | 3.434 | 3.442 | 3.450 | 3.458 | 3.466 | 830 |
| 840 | 3.466 | 3.474 | 3.482 | 3.490 | 3.498 | 3.506 | 3.514 | 3.522 | 3.530 | 3.538 | 3.546 | 840 |
| 850 | 3.546 | 3.554 | 3.562 | 3.570 | 3.578 | 3.586 | 3.594 | 3.602 | 3.610 | 3.618 | 3.626 | 850 |
| 860 | 3.626 | 3.634 | 3.643 | 3.651 | 3.659 | 3.667 | 3.675 | 3.683 | 3.691 | 3.700 | 3.708 | 860 |
| 870 | 3.708 | 3.716 | 3.724 | 3.732 | 3.741 | 3.749 | 3.757 | 3.765 | 3.773 | 3.782 | 3.790 | 870 |
| 880 | 3.790 | 3.798 | 3.806 | 3.815 | 3.823 | 3.831 | 3.840 | 3.848 | 3.856 | 3.865 | 3.873 | 880 |
| 890 | 3.873 | 3.881 | 3.889 | 3.896 | 3.904 | 3.915 | 3.923 | 3.931 | 3.940 | 3.948 | 3.957 | 890 |
| 900 | 3.957 | 3.965 | 3.973 | 3.982 | 3.990 | 3.999 | 4.007 | 4.016 | 4.024 | 4.032 | 4.041 | 900 |
| 910 | 4.041 | 4.049 | 4.058 | 4.066 | 4.075 | 4.083 | 4.092 | 4.100 | 4.109 | 4.117 | 4.126 | 910 |
| 920 | 4.126 | 4.135 | 4.143 | 4.152 | 4.160 | 4.169 | 4.177 | 4.186 | 4.195 | 4.203 | 4.212 | 920 |
| 930 | 4.212 | 4.220 | 4.229 | 4.238 | 4.246 | 4.255 | 4.264 | 4.272 | 4.281 | 4.290 | 4.298 | 930 |
| 940 | 4.298 | 4.307 | 4.316 | 4.325 | 4.333 | 4.342 | 4.351 | 4.359 | 4.368 | 4.377 | 4.386 | 940 |
| 950 | 4.386 | 4.394 | 4.403 | 4.412 | 4.421 | 4.430 | 4.438 | 4.447 | 4.456 | 4.465 | 4.474 | 950 |
| 960 | 4.474 | 4.483 | 4.491 | 4.500 | 4.509 | 4.518 | 4.527 | 4.536 | 4.545 | 4.553 | 4.562 | 960 |
| 970 | 4.562 | 4.571 | 4.580 | 4.589 | 4.598 | 4.607 | 4.616 | 4.625 | 4.634 | 4.643 | 4.652 | 970 |
| 980 | 4.652 | 4.661 | 4.670 | 4.679 | 4.688 | 4.697 | 4.706 | 4.715 | 4.724 | 4.733 | 4.742 | 980 |
| 990 | 4.742 | 4.751 | 4.760 | 4.769 | 4.778 | 4.787 | 4.796 | 4.805 | 4.814 | 4.824 | 4.833 | 990 |
| 1000 | 4.833 | 4.842 | 4.851 | 4.860 | 4.869 | 4.878 | 4.887 | 4.897 | 4.906 | 4.915 | 4.924 | 1000 |
| 1010 | 4.924 | 4.933 | 4.942 | 4.952 | 4.961 | 4.970 | 4.979 | 4.989 | 4.998 | 5.007 | 5.016 | 1010 |
| 1020 | 5.016 | 5.025 | 5.035 | 5.044 | 5.053 | 5.063 | 5.072 | 5.081 | 5.090 | 5.100 | 5.109 | 1020 |
| 1030 | 5.105 | 5.118 | 5.128 | 5.137 | 5.146 | 5.156 | 5.165 | 5.174 | 5.184 | 5.193 | 5.202 | 1030 |
| 1040 | 5.202 | 5.212 | 5.221 | 5.231 | 5.240 | 5.249 | 5.259 | 5.268 | 5.278 | 5.287 | 5.297 | 1040 |
| 1050 | 5.297 | 5.306 | 5.316 | 5.325 | 5.334 | 5.344 | 5.353 | 5.363 | 5.372 | 5.382 | 5.391 | 1050 |
| 1060 | 5.391 | 5.401 | 5.410 | 5.420 | 5.429 | 5.439 | 5.449 | 5.458 | 5.468 | 5.477 | 5.487 | 1060 |
| 1070 | 5.487 | 5.496 | 5.506 | 5.516 | 5.525 | 5.535 | 5.544 | 5.554 | 5.564 | 5.573 | 5.583 | 1070 |
| 1080 | 5.583 | 5.593 | 5.602 | 5.612 | 5.621 | 5.631 | 5.641 | 5.651 | 5.660 | 5.670 | 5.680 | 1080 |
| 1090 | 5.680 | 5.689 | 5.699 | 5.709 | 5.718 | 5.728 | 5.738 | 5.748 | 5.757 | 5.767 | 5.777 | 1090 |
| 1100 | 5.777 | 5.787 | 5.796 | 5.806 | 5.816 | 5.826 | 5.836 | 5.845 | 5.855 | 5.865 | 5.875 | 1100 |
| 1110 | 5.875 | 5.885 | 5.895 | 5.904 | 5.914 | 5.924 | 5.934 | 5.944 | 5.954 | 5.964 | 5.973 | 1110 |
| 1120 | 5.973 | 5.983 | 5.993 | 6.003 | 6.013 | 6.023 | 6.033 | 6.043 | 6.053 | 6.063 | 6.073 | 1120 |
| 1130 | 6.073 | 6.083 | 6.093 | 6.102 | 6.112 | 6.122 | 6.132 | 6.142 | 6.152 | 6.162 | 6.172 | 1130 |
| 1140 | 6.172 | 6.182 | 6.192 | 6.202 | 6.212 | 6.223 | 6.233 | 6.243 | 6.253 | 6.263 | 6.273 | 1140 |
| 1150 | 6.273 | 6.283 | 6.293 | 6.303 | 6.313 | 6.323 | 6.333 | 6.343 | 6.353 | 6.364 | 6.374 | 1150 |
| 1160 | 6.374 | 6.384 | 6.394 | 6.404 | 6.414 | 6.424 | 6.435 | 6.445 | 6.455 | 6.465 | 6.475 | 1160 |
| 1170 | 6.475 | 6.485 | 6.496 | 6.506 | 6.516 | 6.526 | 6.536 | 6.547 | 6.557 | 6.567 | 6.577 | 1170 |
| 1180 | 6.577 | 6.588 | 6.598 | 6.608 | 6.618 | 6.629 | 6.635 | 6.649 | 6.659 | 6.670 | 6.680 | 1180 |
| 1190 | 6.680 | 6.690 | 6.701 | 6.711 | 6.721 | 6.732 | 6.742 | 6.752 | 6.763 | 6.773 | 6.783 | 1190 |
| 1200 | 6.783 | 6.794 | 6.804 | 6.814 | 6.825 | 6.835 | 6.846 | 6.856 | 6.866 | 6.877 | 6.887 | 1200 |
| 1210 | 6.887 | 6.898 | 6.908 | 6.918 | 6.929 | 6.939 | 6.950 | 6.960 | 6.971 | 6.981 | 6.991 | 1210 |
| 1220 | 6.991 | 7.002 | 7.012 | 7.023 | 7.033 | 7.044 | 7.054 | 7.065 | 7.075 | 7.086 | 7.096 | 1220 |
| 1230 | 7.096 | 7.107 | 7.117 | 7.128 | 7.138 | 7.149 | 7.159 | 7.170 | 7.181 | 7.191 | 7.202 | 1230 |
| 1240 | 7.202 | 7.212 | 7.223 | 7.233 | 7.244 | 7.255 | 7.265 | 7.276 | 7.286 | 7.297 | 7.308 | 1240 |
| 1250 | 7.308 | 7.318 | 7.329 | 7.339 | 7.350 | 7.361 | 7.371 | 7.382 | 7.393 | 7.403 | 7.414 | 1250 |
| 1260 | 7.414 | 7.425 | 7.435 | 7.446 | 7.457 | 7.467 | 7.478 | 7.489 | 7.500 | 7.510 | 7.521 | 1260 |
| 1270 | 7.521 | 7.532 | 7.542 | 7.553 | 7.564 | 7.575 | 7.585 | 7.596 | 7.607 | 7.618 | 7.628 | 1270 |
| 1280 | 7.628 | 7.639 | 7.650 | 7.661 | 7.671 | 7.682 | 7.693 | 7.704 | 7.715 | 7.725 | 7.736 | 1280 |
| 1290 | 7.736 | 7.747 | 7.758 | 7.769 | 7.780 | 7.790 | 7.801 | 7.812 | 7.823 | 7.834 | 7.845 | 1290 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 11 (Continued)

TEMPERATURE-EMF FOR TYPE B THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 1300 | 7.845 | 7.855 | 7.866 | 7.877 | 7.888 | 7.899 | 7.910 | 7.921 | 7.932 | 7.943 | 7.953 | 1300 |
| 1310 | 7.953 | 7.964 | 7.975 | 7.986 | 7.997 | 8.008 | 8.019 | 8.030 | 8.041 | 8.052 | 8.063 | 1310 |
| 1320 | 8.063 | 8.074 | 8.085 | 8.096 | 8.107 | 8.118 | 8.128 | 8.139 | 8.150 | 8.161 | 8.172 | 1320 |
| 1330 | 8.172 | 8.183 | 8.194 | 8.205 | 8.216 | 8.227 | 8.238 | 8.249 | 8.261 | 8.272 | 8.283 | 1330 |
| 1340 | 8.283 | 8.294 | 8.305 | 8.316 | 8.327 | 8.338 | 8.349 | 8.360 | 8.371 | 8.382 | 8.393 | 1340 |
| 1350 | 8.393 | 8.404 | 8.415 | 8.426 | 8.437 | 8.449 | 8.460 | 8.471 | 8.482 | 8.493 | 8.504 | 1350 |
| 1360 | 8.504 | 8.515 | 8.526 | 8.538 | 8.549 | 8.560 | 8.571 | 8.582 | 8.593 | 8.604 | 8.616 | 1360 |
| 1370 | 8.616 | 8.627 | 8.638 | 8.649 | 8.660 | 8.671 | 8.683 | 8.694 | 8.705 | 8.716 | 8.727 | 1370 |
| 1380 | 8.727 | 8.738 | 8.750 | 8.761 | 8.772 | 8.783 | 8.795 | 8.806 | 8.817 | 8.828 | 8.839 | 1380 |
| 1390 | 8.839 | 8.851 | 8.862 | 8.873 | 8.884 | 8.896 | 8.907 | 8.918 | 8.929 | 8.941 | 8.952 | 1390 |
| 1400 | 8.952 | 8.963 | 8.974 | 8.986 | 8.997 | 9.008 | 9.020 | 9.031 | 9.042 | 9.053 | 9.065 | 1400 |
| 1410 | 9.065 | 9.076 | 9.087 | 9.099 | 9.110 | 9.121 | 9.133 | 9.144 | 9.155 | 9.167 | 9.178 | 1410 |
| 1420 | 9.178 | 9.189 | 9.201 | 9.212 | 9.223 | 9.235 | 9.246 | 9.257 | 9.269 | 9.280 | 9.291 | 1420 |
| 1430 | 9.291 | 9.303 | 9.314 | 9.326 | 9.337 | 9.348 | 9.360 | 9.371 | 9.382 | 9.394 | 9.405 | 1430 |
| 1440 | 9.405 | 9.417 | 9.428 | 9.439 | 9.451 | 9.462 | 9.474 | 9.485 | 9.497 | 9.508 | 9.519 | 1440 |
| 1450 | 9.519 | 9.531 | 9.542 | 9.554 | 9.565 | 9.577 | 9.588 | 9.599 | 9.611 | 9.622 | 9.634 | 1450 |
| 1460 | 9.634 | 9.645 | 9.657 | 9.668 | 9.680 | 9.691 | 9.703 | 9.714 | 9.726 | 9.737 | 9.748 | 1460 |
| 1470 | 9.748 | 9.760 | 9.771 | 9.783 | 9.794 | 9.806 | 9.817 | 9.829 | 9.840 | 9.852 | 9.863 | 1470 |
| 1480 | 9.863 | 9.875 | 9.886 | 9.898 | 9.909 | 9.921 | 9.933 | 9.944 | 9.956 | 9.967 | 9.979 | 1480 |
| 1490 | 9.979 | 9.990 | 10.002 | 10.013 | 10.025 | 10.036 | 10.048 | 10.059 | 10.071 | 10.082 | 10.094 | 1490 |
| 1500 | 10.094 | 10.106 | 10.117 | 10.129 | 10.140 | 10.152 | 10.163 | 10.175 | 10.187 | 10.198 | 10.210 | 1500 |
| 1510 | 10.210 | 10.221 | 10.233 | 10.244 | 10.256 | 10.268 | 10.279 | 10.291 | 10.302 | 10.314 | 10.325 | 1510 |
| 1520 | 10.325 | 10.337 | 10.349 | 10.360 | 10.372 | 10.383 | 10.395 | 10.407 | 10.418 | 10.430 | 10.441 | 1520 |
| 1530 | 10.441 | 10.453 | 10.465 | 10.476 | 10.488 | 10.500 | 10.511 | 10.523 | 10.534 | 10.546 | 10.558 | 1530 |
| 1540 | 10.558 | 10.569 | 10.581 | 10.593 | 10.604 | 10.616 | 10.627 | 10.639 | 10.651 | 10.662 | 10.674 | 1540 |
| 1550 | 10.674 | 10.686 | 10.697 | 10.709 | 10.721 | 10.732 | 10.744 | 10.756 | 10.767 | 10.779 | 10.790 | 1550 |
| 1560 | 10.790 | 10.802 | 10.814 | 10.825 | 10.837 | 10.849 | 10.860 | 10.872 | 10.884 | 10.895 | 10.907 | 1560 |
| 1570 | 10.907 | 10.919 | 10.930 | 10.942 | 10.954 | 10.965 | 10.977 | 10.989 | 11.000 | 11.012 | 11.024 | 1570 |
| 1580 | 11.024 | 11.035 | 11.047 | 11.059 | 11.070 | 11.082 | 11.094 | 11.105 | 11.117 | 11.129 | 11.141 | 1580 |
| 1590 | 11.141 | 11.152 | 11.164 | 11.176 | 11.187 | 11.199 | 11.211 | 11.222 | 11.234 | 11.246 | 11.257 | 1590 |
| 1600 | 11.257 | 11.269 | 11.281 | 11.292 | 11.304 | 11.316 | 11.328 | 11.339 | 11.351 | 11.363 | 11.374 | 1600 |
| 1610 | 11.374 | 11.386 | 11.398 | 11.409 | 11.421 | 11.433 | 11.444 | 11.456 | 11.468 | 11.480 | 11.491 | 1610 |
| 1620 | 11.491 | 11.503 | 11.515 | 11.526 | 11.538 | 11.550 | 11.561 | 11.573 | 11.585 | 11.597 | 11.608 | 1620 |
| 1630 | 11.608 | 11.620 | 11.632 | 11.643 | 11.655 | 11.667 | 11.678 | 11.690 | 11.702 | 11.714 | 11.725 | 1630 |
| 1640 | 11.725 | 11.737 | 11.749 | 11.760 | 11.772 | 11.784 | 11.795 | 11.807 | 11.819 | 11.830 | 11.842 | 1640 |
| 1650 | 11.842 | 11.854 | 11.866 | 11.877 | 11.889 | 11.901 | 11.912 | 11.924 | 11.936 | 11.947 | 11.959 | 1650 |
| 1660 | 11.959 | 11.971 | 11.983 | 11.994 | 12.006 | 12.018 | 12.029 | 12.041 | 12.053 | 12.064 | 12.076 | 1660 |
| 1670 | 12.076 | 12.088 | 12.099 | 12.111 | 12.123 | 12.134 | 12.146 | 12.158 | 12.170 | 12.181 | 12.193 | 1670 |
| 1680 | 12.193 | 12.205 | 12.216 | 12.228 | 12.240 | 12.251 | 12.263 | 12.275 | 12.286 | 12.298 | 12.310 | 1680 |
| 1690 | 12.310 | 12.321 | 12.333 | 12.345 | 12.356 | 12.368 | 12.380 | 12.391 | 12.403 | 12.415 | 12.426 | 1690 |
| 1700 | 12.426 | 12.438 | 12.450 | 12.461 | 12.473 | 12.485 | 12.496 | 12.508 | 12.520 | 12.531 | 12.543 | 1700 |
| 1710 | 12.543 | 12.555 | 12.566 | 12.578 | 12.590 | 12.601 | 12.613 | 12.624 | 12.636 | 12.648 | 12.659 | 1710 |
| 1720 | 12.659 | 12.671 | 12.683 | 12.694 | 12.706 | 12.718 | 12.729 | 12.741 | 12.752 | 12.764 | 12.776 | 1720 |
| 1730 | 12.776 | 12.787 | 12.799 | 12.811 | 12.822 | 12.834 | 12.845 | 12.857 | 12.869 | 12.880 | 12.892 | 1730 |
| 1740 | 12.892 | 12.903 | 12.915 | 12.927 | 12.938 | 12.950 | 12.961 | 12.973 | 12.985 | 12.996 | 13.008 | 1740 |
| 1750 | 13.008 | 13.019 | 13.031 | 13.043 | 13.054 | 13.066 | 13.077 | 13.089 | 13.100 | 13.112 | 13.124 | 1750 |
| 1760 | 13.124 | 13.135 | 13.147 | 13.158 | 13.170 | 13.181 | 13.193 | 13.204 | 13.216 | 13.228 | 13.239 | 1760 |
| 1770 | 13.239 | 13.251 | 13.262 | 13.274 | 13.285 | 13.297 | 13.308 | 13.320 | 13.331 | 13.343 | 13.354 | 1770 |
| 1780 | 13.354 | 13.366 | 13.378 | 13.389 | 13.401 | 13.412 | 13.424 | 13.435 | 13.447 | 13.458 | 13.470 | 1780 |
| 1790 | 13.470 | 13.481 | 13.493 | 13.504 | 13.516 | 13.527 | 13.539 | 13.550 | 13.562 | 13.573 | 13.585 | 1790 |
| 1800 | 13.585 | 13.596 | 13.607 | 13.619 | 13.630 | 13.642 | 13.653 | 13.665 | 13.676 | 13.688 | 13.699 | 1800 |
| 1810 | 13.699 | 13.711 | 13.722 | 13.733 | 13.745 | 13.756 | 13.768 | 13.779 | 13.791 | 13.802 | 13.814 | 1810 |
| 1820 | 13.814 | | | | | | | | | | | 1820 |

TABLE 12

TEMPERATURE-EMF FOR TYPE E THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| -270 | -9.835 | | | | | | | | | | | -270 |
| -260 | -9.797 | -9.802 | -9.808 | -9.813 | -9.817 | -9.821 | -9.825 | -9.828 | -9.831 | -9.833 | -9.835 | -260 |
| -250 | -9.719 | -9.728 | -9.737 | -9.746 | -9.754 | -9.762 | -9.770 | -9.777 | -9.784 | -9.791 | -9.797 | -250 |
| -240 | -9.604 | -9.617 | -9.630 | -9.642 | -9.654 | -9.666 | -9.677 | -9.688 | -9.699 | -9.709 | -9.719 | -240 |
| -230 | -9.455 | -9.472 | -9.488 | -9.503 | -9.519 | -9.534 | -9.549 | -9.563 | -9.577 | -9.591 | -9.604 | -230 |
| -220 | -9.274 | -9.293 | -9.313 | -9.332 | -9.350 | -9.368 | -9.386 | -9.404 | -9.421 | -9.438 | -9.455 | -220 |
| -210 | -9.063 | -9.085 | -9.107 | -9.129 | -9.151 | -9.172 | -9.193 | -9.214 | -9.234 | -9.254 | -9.274 | -210 |
| -200 | -8.824 | -8.850 | -8.874 | -8.899 | -8.923 | -8.947 | -8.971 | -8.994 | -9.017 | -9.040 | -9.063 | -200 |
| -190 | -8.561 | -8.588 | -8.615 | -8.642 | -8.669 | -8.696 | -8.722 | -8.748 | -8.774 | -8.799 | -8.824 | -190 |
| -180 | -8.273 | -8.303 | -8.333 | -8.362 | -8.391 | -8.420 | -8.449 | -8.477 | -8.505 | -8.533 | -8.561 | -180 |
| -170 | -7.963 | -7.995 | -8.027 | -8.058 | -8.090 | -8.121 | -8.152 | -8.183 | -8.213 | -8.243 | -8.273 | -170 |
| -160 | -7.631 | -7.665 | -7.699 | -7.733 | -7.767 | -7.800 | -7.833 | -7.866 | -7.898 | -7.931 | -7.963 | -160 |
| -150 | -7.279 | -7.315 | -7.351 | -7.387 | -7.422 | -7.458 | -7.493 | -7.528 | -7.562 | -7.597 | -7.631 | -150 |
| -140 | -6.907 | -6.945 | -6.983 | -7.020 | -7.058 | -7.095 | -7.132 | -7.169 | -7.206 | -7.243 | -7.279 | -140 |
| -130 | -6.516 | -6.556 | -6.596 | -6.635 | -6.675 | -6.714 | -6.753 | -6.792 | -6.830 | -6.869 | -6.907 | -130 |
| -120 | -6.107 | -6.149 | -6.190 | -6.231 | -6.273 | -6.314 | -6.354 | -6.395 | -6.436 | -6.476 | -6.516 | -120 |
| -110 | -5.680 | -5.724 | -5.767 | -5.810 | -5.853 | -5.896 | -5.938 | -5.981 | -6.023 | -6.065 | -6.107 | -110 |
| -100 | -5.237 | -5.282 | -5.327 | -5.371 | -5.416 | -5.460 | -5.505 | -5.549 | -5.593 | -5.637 | -5.680 | -100 |
| -90 | -4.777 | -4.824 | -4.870 | -4.916 | -4.963 | -5.009 | -5.055 | -5.100 | -5.146 | -5.191 | -5.237 | -90 |
| -80 | -4.301 | -4.350 | -4.398 | -4.446 | -4.493 | -4.541 | -4.588 | -4.636 | -4.683 | -4.730 | -4.777 | -80 |
| -70 | -3.811 | -3.860 | -3.910 | -3.959 | -4.009 | -4.058 | -4.107 | -4.156 | -4.204 | -4.253 | -4.301 | -70 |
| -60 | -3.306 | -3.357 | -3.408 | -3.459 | -3.509 | -3.560 | -3.610 | -3.661 | -3.711 | -3.761 | -3.811 | -60 |
| -50 | -2.787 | -2.839 | -2.892 | -2.944 | -2.996 | -3.048 | -3.100 | -3.152 | -3.203 | -3.254 | -3.306 | -50 |
| -40 | -2.254 | -2.308 | -2.362 | -2.416 | -2.469 | -2.522 | -2.575 | -2.628 | -2.681 | -2.734 | -2.787 | -40 |
| -30 | -1.709 | -1.764 | -1.819 | -1.874 | -1.929 | -1.983 | -2.038 | -2.092 | -2.146 | -2.200 | -2.254 | -30 |
| -20 | -1.151 | -1.208 | -1.264 | -1.320 | -1.376 | -1.432 | -1.487 | -1.543 | -1.599 | -1.654 | -1.709 | -20 |
| -10 | -0.581 | -0.639 | -0.696 | -0.754 | -0.811 | -0.868 | -0.925 | -0.982 | -1.038 | -1.095 | -1.151 | -10 |
| -0 | 0.000 | -0.059 | -0.117 | -0.176 | -0.234 | -0.292 | -0.350 | -0.408 | -0.466 | -0.524 | -0.581 | -0 |
| 0 | 0.000 | 0.059 | 0.118 | 0.176 | 0.235 | 0.295 | 0.354 | 0.413 | 0.472 | 0.532 | 0.591 | 0 |
| 10 | 0.591 | 0.651 | 0.711 | 0.770 | 0.830 | 0.890 | 0.950 | 1.011 | 1.071 | 1.131 | 1.192 | 10 |
| 20 | 1.192 | 1.252 | 1.313 | 1.373 | 1.434 | 1.495 | 1.556 | 1.617 | 1.678 | 1.739 | 1.801 | 20 |
| 30 | 1.801 | 1.862 | 1.924 | 1.985 | 2.047 | 2.109 | 2.171 | 2.233 | 2.295 | 2.357 | 2.419 | 30 |
| 40 | 2.419 | 2.482 | 2.544 | 2.607 | 2.669 | 2.732 | 2.795 | 2.858 | 2.921 | 2.984 | 3.047 | 40 |
| 50 | 3.047 | 3.110 | 3.173 | 3.237 | 3.300 | 3.364 | 3.428 | 3.491 | 3.555 | 3.619 | 3.683 | 50 |
| 60 | 3.683 | 3.748 | 3.812 | 3.876 | 3.941 | 4.005 | 4.070 | 4.134 | 4.199 | 4.264 | 4.329 | 60 |
| 70 | 4.329 | 4.394 | 4.459 | 4.524 | 4.590 | 4.655 | 4.720 | 4.786 | 4.852 | 4.917 | 4.983 | 70 |
| 80 | 4.983 | 5.049 | 5.115 | 5.181 | 5.247 | 5.314 | 5.380 | 5.446 | 5.513 | 5.579 | 5.646 | 80 |
| 90 | 5.646 | 5.713 | 5.780 | 5.846 | 5.913 | 5.981 | 6.048 | 6.115 | 6.182 | 6.250 | 6.317 | 90 |
| 100 | 6.317 | 6.385 | 6.452 | 6.520 | 6.588 | 6.656 | 6.724 | 6.792 | 6.860 | 6.928 | 6.996 | 100 |
| 110 | 6.996 | 7.064 | 7.133 | 7.201 | 7.270 | 7.339 | 7.407 | 7.476 | 7.545 | 7.614 | 7.683 | 110 |
| 120 | 7.663 | 7.752 | 7.821 | 7.890 | 7.960 | 8.029 | 8.099 | 8.168 | 8.238 | 8.307 | 8.377 | 120 |
| 130 | 8.377 | 8.447 | 8.517 | 8.587 | 8.657 | 8.727 | 8.797 | 8.867 | 8.938 | 9.008 | 9.078 | 130 |
| 140 | 9.078 | 9.149 | 9.220 | 9.290 | 9.361 | 9.432 | 9.503 | 9.573 | 9.644 | 9.715 | 9.787 | 140 |
| 150 | 9.787 | 9.858 | 9.929 | 10.000 | 10.072 | 10.143 | 10.215 | 10.286 | 10.358 | 10.429 | 10.501 | 150 |
| 160 | 10.501 | 10.573 | 10.645 | 10.717 | 10.789 | 10.861 | 10.933 | 11.005 | 11.077 | 11.150 | 11.222 | 160 |
| 170 | 11.222 | 11.294 | 11.367 | 11.439 | 11.512 | 11.585 | 11.657 | 11.730 | 11.803 | 11.876 | 11.949 | 170 |
| 180 | 11.949 | 12.022 | 12.095 | 12.168 | 12.241 | 12.314 | 12.387 | 12.461 | 12.534 | 12.608 | 12.681 | 180 |
| 190 | 12.681 | 12.755 | 12.828 | 12.902 | 12.975 | 13.049 | 13.123 | 13.197 | 13.271 | 13.345 | 13.419 | 190 |
| 200 | 13.419 | 13.493 | 13.567 | 13.641 | 13.715 | 13.789 | 13.864 | 13.938 | 14.012 | 14.087 | 14.161 | 200 |
| 210 | 14.161 | 14.236 | 14.310 | 14.385 | 14.460 | 14.534 | 14.609 | 14.684 | 14.759 | 14.834 | 14.909 | 210 |
| 220 | 14.909 | 14.984 | 15.059 | 15.134 | 15.209 | 15.284 | 15.359 | 15.435 | 15.510 | 15.585 | 15.661 | 220 |
| 230 | 15.661 | 15.736 | 15.812 | 15.887 | 15.963 | 16.038 | 16.114 | 16.190 | 16.266 | 16.341 | 16.417 | 230 |
| 240 | 16.417 | 16.493 | 16.569 | 16.645 | 16.721 | 16.797 | 16.873 | 16.949 | 17.025 | 17.101 | 17.178 | 240 |
| 250 | 17.178 | 17.254 | 17.330 | 17.406 | 17.483 | 17.559 | 17.636 | 17.712 | 17.789 | 17.865 | 17.942 | 250 |
| 260 | 17.942 | 18.018 | 18.095 | 18.172 | 18.248 | 18.325 | 18.402 | 18.479 | 18.556 | 18.633 | 18.710 | 260 |
| 270 | 18.710 | 18.787 | 18.864 | 18.941 | 19.018 | 19.095 | 19.172 | 19.249 | 19.326 | 19.404 | 19.481 | 270 |
| 280 | 19.481 | 19.558 | 19.636 | 19.713 | 19.790 | 19.868 | 19.945 | 20.023 | 20.100 | 20.178 | 20.256 | 280 |
| 290 | 20.256 | 20.333 | 20.411 | 20.488 | 20.566 | 20.644 | 20.722 | 20.800 | 20.877 | 20.955 | 21.033 | 290 |
| 300 | 21.033 | 21.111 | 21.189 | 21.267 | 21.345 | 21.423 | 21.501 | 21.579 | 21.657 | 21.735 | 21.814 | 300 |
| 310 | 21.814 | 21.892 | 21.970 | 22.048 | 22.127 | 22.205 | 22.283 | 22.362 | 22.440 | 22.518 | 22.597 | 310 |
| 320 | 22.597 | 22.675 | 22.754 | 22.832 | 22.911 | 22.989 | 23.068 | 23.147 | 23.225 | 23.304 | 23.383 | 320 |
| 330 | 23.383 | 23.461 | 23.540 | 23.619 | 23.698 | 23.777 | 23.855 | 23.934 | 24.013 | 24.092 | 24.171 | 330 |
| 340 | 24.171 | 24.250 | 24.329 | 24.408 | 24.487 | 24.566 | 24.645 | 24.724 | 24.803 | 24.882 | 24.961 | 340 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 12 (Continued)

TEMPERATURE-EMF FOR TYPE E THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 350 | 24.961 | 25.041 | 25.120 | 25.199 | 25.278 | 25.357 | 25.437 | 25.516 | 25.595 | 25.675 | 25.754 | 350 |
| 360 | 25.754 | 25.833 | 25.913 | 25.992 | 26.072 | 26.151 | 26.230 | 26.310 | 26.389 | 26.469 | 26.549 | 360 |
| 370 | 26.549 | 26.628 | 26.708 | 26.787 | 26.867 | 26.947 | 27.026 | 27.106 | 27.186 | 27.265 | 27.345 | 370 |
| 380 | 27.345 | 27.425 | 27.504 | 27.584 | 27.664 | 27.744 | 27.824 | 27.903 | 27.983 | 28.063 | 28.143 | 380 |
| 390 | 28.143 | 28.223 | 28.303 | 28.383 | 28.463 | 28.543 | 28.623 | 28.703 | 28.783 | 28.863 | 28.943 | 390 |
| 400 | 28.943 | 29.023 | 29.103 | 29.183 | 29.263 | 29.343 | 29.423 | 29.503 | 29.584 | 29.664 | 29.744 | 400 |
| 410 | 29.744 | 29.824 | 29.904 | 29.984 | 30.065 | 30.145 | 30.225 | 30.305 | 30.386 | 30.466 | 30.546 | 410 |
| 420 | 30.546 | 30.627 | 30.707 | 30.787 | 30.868 | 30.948 | 31.028 | 31.109 | 31.189 | 31.270 | 31.350 | 420 |
| 430 | 31.350 | 31.430 | 31.511 | 31.591 | 31.672 | 31.752 | 31.833 | 31.913 | 31.994 | 32.074 | 32.155 | 430 |
| 440 | 32.155 | 32.235 | 32.316 | 32.396 | 32.477 | 32.557 | 32.638 | 32.719 | 32.799 | 32.880 | 32.960 | 440 |
| 450 | 32.960 | 33.041 | 33.122 | 33.202 | 33.283 | 33.364 | 33.444 | 33.525 | 33.605 | 33.686 | 33.767 | 450 |
| 460 | 33.767 | 33.848 | 33.928 | 34.009 | 34.090 | 34.170 | 34.251 | 34.332 | 34.413 | 34.493 | 34.574 | 460 |
| 470 | 34.574 | 34.655 | 34.736 | 34.816 | 34.897 | 34.978 | 35.059 | 35.140 | 35.220 | 35.301 | 35.382 | 470 |
| 480 | 35.382 | 35.463 | 35.544 | 35.624 | 35.705 | 35.786 | 35.867 | 35.948 | 36.029 | 36.109 | 36.190 | 480 |
| 490 | 36.190 | 36.271 | 36.352 | 36.433 | 36.514 | 36.595 | 36.675 | 36.756 | 36.837 | 36.918 | 36.999 | 490 |
| 500 | 36.999 | 37.080 | 37.161 | 37.242 | 37.323 | 37.403 | 37.484 | 37.565 | 37.646 | 37.727 | 37.808 | 500 |
| 510 | 37.808 | 37.889 | 37.970 | 38.051 | 38.132 | 38.213 | 38.293 | 38.374 | 38.455 | 38.536 | 38.617 | 510 |
| 520 | 38.617 | 38.698 | 38.779 | 38.860 | 38.941 | 39.022 | 39.103 | 39.184 | 39.264 | 39.345 | 39.426 | 520 |
| 530 | 39.426 | 39.507 | 39.588 | 39.669 | 39.750 | 39.831 | 39.912 | 39.993 | 40.074 | 40.155 | 40.236 | 530 |
| 540 | 40.236 | 40.316 | 40.397 | 40.478 | 40.559 | 40.640 | 40.721 | 40.802 | 40.883 | 40.964 | 41.045 | 540 |
| 550 | 41.045 | 41.125 | 41.206 | 41.287 | 41.368 | 41.449 | 41.530 | 41.611 | 41.692 | 41.773 | 41.853 | 550 |
| 560 | 41.853 | 41.934 | 42.015 | 42.096 | 42.177 | 42.258 | 42.339 | 42.419 | 42.500 | 42.581 | 42.662 | 560 |
| 570 | 42.662 | 42.743 | 42.824 | 42.904 | 42.985 | 43.066 | 43.147 | 43.228 | 43.308 | 43.389 | 43.470 | 570 |
| 580 | 43.470 | 43.551 | 43.632 | 43.712 | 43.793 | 43.874 | 43.955 | 44.035 | 44.116 | 44.197 | 44.278 | 580 |
| 590 | 44.278 | 44.358 | 44.439 | 44.520 | 44.601 | 44.681 | 44.762 | 44.843 | 44.923 | 45.004 | 45.085 | 590 |
| 600 | 45.085 | 45.165 | 45.246 | 45.327 | 45.407 | 45.488 | 45.569 | 45.649 | 45.730 | 45.811 | 45.891 | 600 |
| 610 | 45.891 | 45.972 | 46.052 | 46.133 | 46.213 | 46.294 | 46.375 | 46.455 | 46.536 | 46.616 | 46.697 | 610 |
| 620 | 46.697 | 46.777 | 46.858 | 46.938 | 47.019 | 47.099 | 47.180 | 47.260 | 47.341 | 47.421 | 47.502 | 620 |
| 630 | 47.502 | 47.582 | 47.663 | 47.743 | 47.824 | 47.904 | 47.984 | 48.065 | 48.145 | 48.226 | 48.306 | 630 |
| 640 | 48.306 | 48.386 | 48.467 | 48.547 | 48.627 | 48.708 | 48.788 | 48.868 | 48.949 | 49.029 | 49.109 | 640 |
| 650 | 49.109 | 49.189 | 49.270 | 49.350 | 49.430 | 49.510 | 49.591 | 49.671 | 49.751 | 49.831 | 49.911 | 650 |
| 660 | 49.911 | 49.992 | 50.072 | 50.152 | 50.232 | 50.312 | 50.392 | 50.472 | 50.553 | 50.633 | 50.713 | 660 |
| 670 | 50.713 | 50.793 | 50.873 | 50.953 | 51.033 | 51.113 | 51.193 | 51.273 | 51.353 | 51.433 | 51.513 | 670 |
| 680 | 51.513 | 51.593 | 51.673 | 51.753 | 51.833 | 51.913 | 51.993 | 52.073 | 52.152 | 52.232 | 52.312 | 680 |
| 690 | 52.312 | 52.392 | 52.472 | 52.552 | 52.632 | 52.711 | 52.791 | 52.871 | 52.951 | 53.031 | 53.110 | 690 |
| 700 | 53.110 | 53.190 | 53.270 | 53.350 | 53.429 | 53.509 | 53.589 | 53.668 | 53.748 | 53.828 | 53.907 | 700 |
| 710 | 53.907 | 53.987 | 54.066 | 54.146 | 54.226 | 54.305 | 54.385 | 54.464 | 54.544 | 54.623 | 54.703 | 710 |
| 720 | 54.703 | 54.782 | 54.862 | 54.941 | 55.021 | 55.100 | 55.180 | 55.259 | 55.339 | 55.418 | 55.498 | 720 |
| 730 | 55.498 | 55.577 | 55.656 | 55.736 | 55.815 | 55.894 | 55.974 | 56.053 | 56.132 | 56.212 | 56.291 | 730 |
| 740 | 56.291 | 56.370 | 56.449 | 56.529 | 56.608 | 56.687 | 56.766 | 56.845 | 56.924 | 57.004 | 57.083 | 740 |
| 750 | 57.083 | 57.162 | 57.241 | 57.320 | 57.399 | 57.478 | 57.557 | 57.636 | 57.715 | 57.794 | 57.873 | 750 |
| 760 | 57.873 | 57.952 | 58.031 | 58.110 | 58.189 | 58.268 | 58.347 | 58.426 | 58.505 | 58.584 | 58.663 | 760 |
| 770 | 58.663 | 58.742 | 58.820 | 58.899 | 58.978 | 59.057 | 59.136 | 59.214 | 59.293 | 59.372 | 59.451 | 770 |
| 780 | 59.451 | 59.529 | 59.608 | 59.687 | 59.765 | 59.844 | 59.923 | 60.001 | 60.080 | 60.159 | 60.237 | 780 |
| 790 | 60.237 | 60.316 | 60.394 | 60.473 | 60.551 | 60.630 | 60.708 | 60.787 | 60.865 | 60.944 | 61.022 | 790 |
| 800 | 61.022 | 61.101 | 61.179 | 61.258 | 61.336 | 61.414 | 61.493 | 61.571 | 61.649 | 61.728 | 61.806 | 800 |
| 810 | 61.806 | 61.884 | 61.962 | 62.041 | 62.119 | 62.197 | 62.275 | 62.353 | 62.432 | 62.510 | 62.588 | 810 |
| 820 | 62.588 | 62.666 | 62.744 | 62.822 | 62.900 | 62.978 | 63.056 | 63.134 | 63.212 | 63.290 | 63.368 | 820 |
| 830 | 63.368 | 63.446 | 63.524 | 63.602 | 63.680 | 63.758 | 63.836 | 63.914 | 63.992 | 64.069 | 64.147 | 830 |
| 840 | 64.147 | 64.225 | 64.303 | 64.380 | 64.458 | 64.536 | 64.614 | 64.691 | 64.769 | 64.847 | 64.924 | 840 |
| 850 | 64.924 | 65.002 | 65.080 | 65.157 | 65.235 | 65.312 | 65.390 | 65.467 | 65.545 | 65.622 | 65.700 | 850 |
| 860 | 65.700 | 65.777 | 65.855 | 65.932 | 66.009 | 66.087 | 66.164 | 66.241 | 66.319 | 66.396 | 66.473 | 860 |
| 870 | 66.473 | 66.551 | 66.628 | 66.705 | 66.782 | 66.859 | 66.937 | 67.014 | 67.091 | 67.168 | 67.245 | 870 |
| 880 | 67.245 | 67.322 | 67.399 | 67.476 | 67.553 | 67.630 | 67.707 | 67.784 | 67.861 | 67.938 | 68.015 | 880 |
| 890 | 68.015 | 68.092 | 68.169 | 68.246 | 68.323 | 68.399 | 68.476 | 68.553 | 68.630 | 68.706 | 68.783 | 890 |
| 900 | 68.783 | 68.860 | 68.936 | 69.013 | 69.090 | 69.166 | 69.243 | 69.320 | 69.396 | 69.473 | 69.549 | 900 |
| 910 | 69.549 | 69.626 | 69.702 | 69.779 | 69.855 | 69.931 | 70.008 | 70.084 | 70.161 | 70.237 | 70.313 | 910 |
| 920 | 70.313 | 70.390 | 70.466 | 70.542 | 70.618 | 70.694 | 70.771 | 70.847 | 70.923 | 70.999 | 71.075 | 920 |
| 930 | 71.075 | 71.151 | 71.227 | 71.303 | 71.380 | 71.456 | 71.532 | 71.608 | 71.683 | 71.759 | 71.835 | 930 |
| 940 | 71.835 | 71.911 | 71.987 | 72.063 | 72.139 | 72.215 | 72.290 | 72.366 | 72.442 | 72.518 | 72.593 | 940 |
| 950 | 72.593 | 72.669 | 72.745 | 72.820 | 72.896 | 72.972 | 73.047 | 73.123 | 73.199 | 73.274 | 73.350 | 950 |
| 960 | 73.350 | 73.425 | 73.501 | 73.576 | 73.652 | 73.727 | 73.802 | 73.876 | 73.953 | 74.029 | 74.104 | 960 |
| 970 | 74.104 | 74.179 | 74.255 | 74.330 | 74.405 | 74.480 | 74.556 | 74.631 | 74.706 | 74.781 | 74.857 | 970 |
| 980 | 74.857 | 74.932 | 75.007 | 75.082 | 75.157 | 75.232 | 75.307 | 75.382 | 75.458 | 75.533 | 75.608 | 980 |
| 990 | 75.608 | 75.683 | 75.758 | 75.833 | 75.908 | 75.983 | 76.058 | 76.133 | 76.208 | 76.283 | 76.358 | 990 |
| 1000 | 76.358 | | | | | | | | | | | 1000 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 13

TEMPERATURE-EMF FOR TYPE J THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| -210 | -8.096 | | | | | | | | | | | -210 |
| -200 | -7.890 | -7.912 | -7.934 | -7.955 | -7.976 | -7.996 | -8.017 | -8.037 | -8.057 | -8.076 | -8.096 | -200 |
| -190 | -7.659 | -7.683 | -7.707 | -7.731 | -7.755 | -7.778 | -7.801 | -7.824 | -7.846 | -7.868 | -7.890 | -190 |
| -180 | -7.402 | -7.429 | -7.455 | -7.482 | -7.508 | -7.533 | -7.559 | -7.584 | -7.609 | -7.634 | -7.659 | -180 |
| -170 | -7.122 | -7.151 | -7.180 | -7.209 | -7.237 | -7.265 | -7.293 | -7.321 | -7.348 | -7.375 | -7.402 | -170 |
| -160 | -6.821 | -6.852 | -6.883 | -6.914 | -6.944 | -6.974 | -7.004 | -7.034 | -7.064 | -7.093 | -7.122 | -160 |
| -150 | -6.499 | -6.532 | -6.565 | -6.598 | -6.630 | -6.663 | -6.695 | -6.727 | -6.758 | -6.790 | -6.821 | -150 |
| -140 | -6.159 | -6.194 | -6.228 | -6.263 | -6.297 | -6.331 | -6.365 | -6.399 | -6.433 | -6.466 | -6.499 | -140 |
| -130 | -5.801 | -5.837 | -5.874 | -5.910 | -5.946 | -5.982 | -6.018 | -6.053 | -6.089 | -6.124 | -6.159 | -130 |
| -120 | -5.426 | -5.464 | -5.502 | -5.540 | -5.578 | -5.615 | -5.653 | -5.690 | -5.727 | -5.764 | -5.801 | -120 |
| -110 | -5.036 | -5.076 | -5.115 | -5.155 | -5.194 | -5.233 | -5.272 | -5.311 | -5.349 | -5.388 | -5.426 | -110 |
| -100 | -4.632 | -4.673 | -4.714 | -4.755 | -4.795 | -4.836 | -4.876 | -4.916 | -4.956 | -4.996 | -5.036 | -100 |
| -90 | -4.215 | -4.257 | -4.299 | -4.341 | -4.383 | -4.425 | -4.467 | -4.508 | -4.550 | -4.591 | -4.632 | -90 |
| -80 | -3.785 | -3.829 | -3.872 | -3.915 | -3.958 | -4.001 | -4.044 | -4.087 | -4.130 | -4.172 | -4.215 | -80 |
| -70 | -3.344 | -3.389 | -3.433 | -3.478 | -3.522 | -3.566 | -3.610 | -3.654 | -3.698 | -3.742 | -3.785 | -70 |
| -60 | -2.892 | -2.938 | -2.984 | -3.029 | -3.074 | -3.120 | -3.165 | -3.210 | -3.255 | -3.299 | -3.344 | -60 |
| -50 | -2.431 | -2.478 | -2.524 | -2.570 | -2.617 | -2.663 | -2.709 | -2.755 | -2.801 | -2.841 | -2.892 | -50 |
| -40 | -1.960 | -2.008 | -2.055 | -2.102 | -2.150 | -2.197 | -2.244 | -2.291 | -2.338 | -2.384 | -2.431 | -40 |
| -30 | -1.481 | -1.530 | -1.578 | -1.626 | -1.674 | -1.722 | -1.770 | -1.818 | -1.865 | -1.913 | -1.960 | -30 |
| -20 | -0.995 | -1.044 | -1.093 | -1.141 | -1.190 | -1.239 | -1.288 | -1.336 | -1.385 | -1.433 | -1.481 | -20 |
| -10 | -0.501 | -0.550 | -0.600 | -0.650 | -0.699 | -0.748 | -0.798 | -0.847 | -0.896 | -0.945 | -0.995 | -10 |
| 0 | 0.000 | -0.050 | -0.101 | -0.151 | -0.201 | -0.251 | -0.301 | -0.351 | -0.401 | -0.451 | -0.501 | 0 |
| 0 | 0.000 | 0.050 | 0.101 | 0.151 | 0.202 | 0.253 | 0.303 | 0.354 | 0.405 | 0.456 | 0.507 | 0 |
| 10 | 0.507 | 0.558 | 0.609 | 0.660 | 0.711 | 0.762 | 0.813 | 0.865 | 0.916 | 0.967 | 1.019 | 10 |
| 20 | 1.019 | 1.070 | 1.122 | 1.174 | 1.225 | 1.277 | 1.329 | 1.381 | 1.432 | 1.484 | 1.536 | 20 |
| 30 | 1.536 | 1.588 | 1.640 | 1.693 | 1.745 | 1.797 | 1.849 | 1.901 | 1.954 | 2.006 | 2.058 | 30 |
| 40 | 2.058 | 2.111 | 2.163 | 2.216 | 2.268 | 2.321 | 2.374 | 2.426 | 2.479 | 2.532 | 2.585 | 40 |
| 50 | 2.585 | 2.638 | 2.691 | 2.743 | 2.796 | 2.849 | 2.902 | 2.956 | 3.009 | 3.062 | 3.115 | 50 |
| 60 | 3.115 | 3.168 | 3.221 | 3.275 | 3.328 | 3.381 | 3.435 | 3.488 | 3.542 | 3.595 | 3.649 | 60 |
| 70 | 3.649 | 3.702 | 3.756 | 3.809 | 3.863 | 3.917 | 3.971 | 4.024 | 4.078 | 4.132 | 4.186 | 70 |
| 80 | 4.186 | 4.239 | 4.293 | 4.347 | 4.401 | 4.455 | 4.509 | 4.563 | 4.617 | 4.671 | 4.725 | 80 |
| 90 | 4.725 | 4.780 | 4.834 | 4.888 | 4.942 | 4.996 | 5.050 | 5.105 | 5.159 | 5.213 | 5.268 | 90 |
| 100 | 5.268 | 5.322 | 5.376 | 5.431 | 5.485 | 5.540 | 5.594 | 5.649 | 5.703 | 5.758 | 5.812 | 100 |
| 110 | 5.812 | 5.867 | 5.921 | 5.976 | 6.031 | 6.085 | 6.140 | 6.195 | 6.249 | 6.304 | 6.359 | 110 |
| 120 | 6.359 | 6.414 | 6.468 | 6.523 | 6.578 | 6.633 | 6.688 | 6.742 | 6.797 | 6.852 | 6.907 | 120 |
| 130 | 6.907 | 6.962 | 7.017 | 7.072 | 7.127 | 7.182 | 7.237 | 7.292 | 7.347 | 7.402 | 7.457 | 130 |
| 140 | 7.457 | 7.512 | 7.567 | 7.622 | 7.677 | 7.732 | 7.787 | 7.843 | 7.898 | 7.953 | 8.008 | 140 |
| 150 | 8.008 | 8.063 | 8.118 | 8.174 | 8.229 | 8.284 | 8.339 | 8.394 | 8.450 | 8.505 | 8.560 | 150 |
| 160 | 8.560 | 8.616 | 8.671 | 8.726 | 8.781 | 8.837 | 8.892 | 8.947 | 9.003 | 9.058 | 9.113 | 160 |
| 170 | 9.113 | 9.169 | 9.224 | 9.279 | 9.335 | 9.390 | 9.446 | 9.501 | 9.556 | 9.612 | 9.667 | 170 |
| 180 | 9.667 | 9.723 | 9.778 | 9.834 | 9.889 | 9.944 | 10.000 | 10.055 | 10.111 | 10.166 | 10.222 | 180 |
| 190 | 10.222 | 10.277 | 10.333 | 10.388 | 10.444 | 10.499 | 10.555 | 10.610 | 10.666 | 10.721 | 10.777 | 190 |
| 200 | 10.777 | 10.832 | 10.888 | 10.943 | 10.999 | 11.054 | 11.110 | 11.165 | 11.221 | 11.276 | 11.332 | 200 |
| 210 | 11.332 | 11.387 | 11.443 | 11.498 | 11.554 | 11.609 | 11.665 | 11.720 | 11.776 | 11.831 | 11.887 | 210 |
| 220 | 11.887 | 11.943 | 11.998 | 12.054 | 12.109 | 12.165 | 12.220 | 12.276 | 12.331 | 12.387 | 12.442 | 220 |
| 230 | 12.442 | 12.498 | 12.553 | 12.609 | 12.664 | 12.720 | 12.776 | 12.831 | 12.887 | 12.942 | 12.998 | 230 |
| 240 | 12.998 | 13.053 | 13.109 | 13.164 | 13.220 | 13.275 | 13.331 | 13.386 | 13.442 | 13.497 | 13.553 | 240 |
| 250 | 13.553 | 13.608 | 13.664 | 13.719 | 13.775 | 13.830 | 13.886 | 13.941 | 13.997 | 14.052 | 14.108 | 250 |
| 260 | 14.108 | 14.163 | 14.219 | 14.274 | 14.330 | 14.385 | 14.441 | 14.496 | 14.552 | 14.607 | 14.663 | 260 |
| 270 | 14.663 | 14.718 | 14.774 | 14.829 | 14.885 | 14.940 | 14.995 | 15.051 | 15.106 | 15.162 | 15.217 | 270 |
| 280 | 15.217 | 15.273 | 15.328 | 15.383 | 15.439 | 15.494 | 15.550 | 15.605 | 15.661 | 15.716 | 15.771 | 280 |
| 290 | 15.771 | 15.827 | 15.882 | 15.938 | 15.993 | 16.048 | 16.104 | 16.159 | 16.214 | 16.270 | 16.325 | 290 |
| 300 | 16.325 | 16.380 | 16.436 | 16.491 | 16.547 | 16.602 | 16.657 | 16.713 | 16.768 | 16.823 | 16.879 | 300 |
| 310 | 16.879 | 16.934 | 16.989 | 17.044 | 17.100 | 17.155 | 17.210 | 17.266 | 17.321 | 17.376 | 17.432 | 310 |
| 320 | 17.432 | 17.487 | 17.542 | 17.597 | 17.653 | 17.708 | 17.763 | 17.818 | 17.874 | 17.929 | 17.984 | 320 |
| 330 | 17.984 | 18.039 | 18.095 | 18.150 | 18.205 | 18.260 | 18.316 | 18.371 | 18.426 | 18.481 | 18.537 | 330 |
| 340 | 18.537 | 18.592 | 18.647 | 18.702 | 18.757 | 18.813 | 18.868 | 18.923 | 18.978 | 19.033 | 19.089 | 340 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 13 (Continued)

TEMPERATURE-EMF FOR TYPE J THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68) REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 350 | 19.089 | 19.144 | 19.199 | 19.254 | 19.309 | 19.364 | 19.420 | 19.475 | 19.530 | 19.585 | 19.640 | 350 |
| 360 | 19.640 | 19.695 | 19.751 | 19.806 | 19.861 | 19.916 | 19.971 | 20.026 | 20.081 | 20.137 | 20.192 | 360 |
| 370 | 20.192 | 20.247 | 20.302 | 20.357 | 20.412 | 20.467 | 20.523 | 20.578 | 20.633 | 20.688 | 20.743 | 370 |
| 380 | 20.743 | 20.798 | 20.853 | 20.909 | 20.964 | 21.019 | 21.074 | 21.129 | 21.184 | 21.239 | 21.295 | 380 |
| 390 | 21.295 | 21.350 | 21.405 | 21.460 | 21.515 | 21.570 | 21.625 | 21.680 | 21.736 | 21.791 | 21.846 | 390 |
| 400 | 21.846 | 21.901 | 21.956 | 22.011 | 22.066 | 22.122 | 22.177 | 22.232 | 22.287 | 22.342 | 22.397 | 400 |
| 410 | 22.397 | 22.453 | 22.508 | 22.563 | 22.618 | 22.673 | 22.728 | 22.784 | 22.839 | 22.894 | 22.949 | 410 |
| 420 | 22.949 | 23.004 | 23.060 | 23.115 | 23.170 | 23.225 | 23.280 | 23.336 | 23.391 | 23.446 | 23.501 | 420 |
| 430 | 23.501 | 23.556 | 23.612 | 23.667 | 23.722 | 23.777 | 23.833 | 23.888 | 23.943 | 23.999 | 24.054 | 430 |
| 440 | 24.054 | 24.109 | 24.164 | 24.220 | 24.275 | 24.330 | 24.386 | 24.441 | 24.496 | 24.552 | 24.607 | 440 |
| 450 | 24.607 | 24.662 | 24.718 | 24.773 | 24.829 | 24.884 | 24.939 | 24.995 | 25.050 | 25.106 | 25.161 | 450 |
| 460 | 25.161 | 25.217 | 25.272 | 25.327 | 25.383 | 25.438 | 25.494 | 25.549 | 25.605 | 25.661 | 25.716 | 460 |
| 470 | 25.716 | 25.772 | 25.827 | 25.883 | 25.938 | 25.994 | 26.050 | 26.105 | 26.161 | 26.216 | 26.272 | 470 |
| 480 | 26.272 | 26.328 | 26.383 | 26.439 | 26.495 | 26.551 | 26.606 | 26.662 | 26.718 | 26.774 | 26.829 | 480 |
| 490 | 26.829 | 26.885 | 26.941 | 26.997 | 27.053 | 27.109 | 27.165 | 27.220 | 27.276 | 27.332 | 27.388 | 490 |
| 500 | 27.388 | 27.444 | 27.500 | 27.556 | 27.612 | 27.668 | 27.724 | 27.780 | 27.836 | 27.893 | 27.949 | 500 |
| 510 | 27.949 | 28.005 | 28.061 | 28.117 | 28.173 | 28.230 | 28.286 | 28.342 | 28.398 | 28.455 | 28.511 | 510 |
| 520 | 28.511 | 28.567 | 28.624 | 28.680 | 28.736 | 28.793 | 28.849 | 28.906 | 28.962 | 29.019 | 29.075 | 520 |
| 530 | 29.075 | 29.132 | 29.188 | 29.245 | 29.301 | 29.358 | 29.415 | 29.471 | 29.528 | 29.585 | 29.642 | 530 |
| 540 | 29.642 | 29.698 | 29.755 | 29.812 | 29.869 | 29.926 | 29.983 | 30.039 | 30.096 | 30.153 | 30.210 | 540 |
| 550 | 30.210 | 30.267 | 30.324 | 30.381 | 30.439 | 30.496 | 30.553 | 30.610 | 30.667 | 30.724 | 30.782 | 550 |
| 560 | 30.782 | 30.839 | 30.896 | 30.954 | 31.011 | 31.068 | 31.126 | 31.183 | 31.241 | 31.298 | 31.356 | 560 |
| 570 | 31.356 | 31.413 | 31.471 | 31.528 | 31.586 | 31.644 | 31.702 | 31.759 | 31.817 | 31.875 | 31.933 | 570 |
| 580 | 31.933 | 31.991 | 32.048 | 32.106 | 32.164 | 32.222 | 32.280 | 32.338 | 32.396 | 32.455 | 32.513 | 580 |
| 590 | 32.513 | 32.571 | 32.629 | 32.687 | 32.746 | 32.804 | 32.862 | 32.921 | 32.979 | 33.038 | 33.096 | 590 |
| 600 | 33.096 | 33.155 | 33.213 | 33.272 | 33.330 | 33.389 | 33.448 | 33.506 | 33.565 | 33.624 | 33.683 | 600 |
| 610 | 33.683 | 33.742 | 33.800 | 33.859 | 33.918 | 33.977 | 34.036 | 34.095 | 34.155 | 34.214 | 34.273 | 610 |
| 620 | 34.273 | 34.332 | 34.391 | 34.451 | 34.510 | 34.569 | 34.629 | 34.688 | 34.748 | 34.807 | 34.867 | 620 |
| 630 | 34.867 | 34.926 | 34.986 | 35.046 | 35.105 | 35.165 | 35.225 | 35.285 | 35.344 | 35.404 | 35.464 | 630 |
| 640 | 35.464 | 35.524 | 35.584 | 35.644 | 35.704 | 35.764 | 35.825 | 35.885 | 35.945 | 36.005 | 36.066 | 640 |
| 650 | 36.066 | 36.126 | 36.186 | 36.247 | 36.307 | 36.368 | 36.428 | 36.489 | 36.549 | 36.610 | 36.671 | 650 |
| 660 | 36.671 | 36.732 | 36.792 | 36.853 | 36.914 | 36.975 | 37.036 | 37.097 | 37.158 | 37.219 | 37.280 | 660 |
| 670 | 37.280 | 37.341 | 37.402 | 37.463 | 37.525 | 37.586 | 37.647 | 37.709 | 37.770 | 37.831 | 37.893 | 670 |
| 680 | 37.893 | 37.954 | 38.016 | 38.078 | 38.139 | 38.201 | 38.262 | 38.324 | 38.386 | 38.448 | 38.510 | 680 |
| 690 | 38.510 | 38.572 | 38.633 | 38.695 | 38.757 | 38.819 | 38.882 | 38.944 | 39.006 | 39.068 | 39.130 | 690 |
| 700 | 39.130 | 39.192 | 39.255 | 39.317 | 39.379 | 39.442 | 39.504 | 39.567 | 39.629 | 39.692 | 39.754 | 700 |
| 710 | 39.754 | 39.817 | 39.880 | 39.942 | 40.005 | 40.068 | 40.131 | 40.193 | 40.256 | 40.319 | 40.382 | 710 |
| 720 | 40.382 | 40.445 | 40.508 | 40.571 | 40.634 | 40.697 | 40.760 | 40.823 | 40.886 | 40.950 | 41.013 | 720 |
| 730 | 41.013 | 41.076 | 41.139 | 41.203 | 41.266 | 41.329 | 41.393 | 41.456 | 41.520 | 41.583 | 41.647 | 730 |
| 740 | 41.647 | 41.710 | 41.774 | 41.837 | 41.901 | 41.965 | 42.028 | 42.092 | 42.156 | 42.219 | 42.283 | 740 |
| 750 | 42.283 | 42.347 | 42.411 | 42.475 | 42.538 | 42.602 | 42.666 | 42.730 | 42.794 | 42.858 | 42.922 | 750 |
| 760 | 42.922 | | | | | | | | | | | 760 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 14

TEMPERATURE-EMF FOR TYPE K THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| -270 | -6.458 | | | | | | | | | | | -270 |
| -260 | -6.441 | -6.444 | -6.446 | -6.448 | -6.450 | -6.452 | -6.453 | -6.455 | -6.456 | -6.457 | -6.458 | -260 |
| -250 | -6.404 | -6.408 | -6.413 | -6.417 | -6.421 | -6.425 | -6.429 | -6.432 | -6.435 | -6.438 | -6.441 | -250 |
| -240 | -6.344 | -6.351 | -6.358 | -6.364 | -6.371 | -6.377 | -6.382 | -6.388 | -6.394 | -6.399 | -6.404 | -240 |
| -230 | -6.262 | -6.271 | -6.280 | -6.289 | -6.297 | -6.306 | -6.314 | -6.322 | -6.329 | -6.337 | -6.344 | -230 |
| -220 | -6.158 | -6.170 | -6.181 | -6.192 | -6.202 | -6.213 | -6.223 | -6.233 | -6.243 | -6.253 | -6.262 | -220 |
| -210 | -6.035 | -6.048 | -6.061 | -6.074 | -6.087 | -6.099 | -6.111 | -6.123 | -6.135 | -6.147 | -6.158 | -210 |
| -200 | -5.891 | -5.907 | -5.922 | -5.936 | -5.951 | -5.965 | -5.980 | -5.994 | -6.007 | -6.021 | -6.035 | -200 |
| -190 | -5.730 | -5.747 | -5.763 | -5.780 | -5.796 | -5.813 | -5.829 | -5.845 | -5.860 | -5.876 | -5.891 | -190 |
| -180 | -5.550 | -5.569 | -5.587 | -5.606 | -5.624 | -5.642 | -5.660 | -5.678 | -5.695 | -5.712 | -5.730 | -180 |
| -170 | -5.354 | -5.374 | -5.394 | -5.414 | -5.434 | -5.454 | -5.474 | -5.493 | -5.512 | -5.531 | -5.550 | -170 |
| -160 | -5.141 | -5.163 | -5.185 | -5.207 | -5.228 | -5.249 | -5.271 | -5.292 | -5.313 | -5.333 | -5.354 | -160 |
| -150 | -4.912 | -4.936 | -4.959 | -4.983 | -5.006 | -5.029 | -5.051 | -5.074 | -5.097 | -5.119 | -5.141 | -150 |
| -140 | -4.669 | -4.694 | -4.719 | -4.743 | -4.768 | -4.792 | -4.817 | -4.841 | -4.865 | -4.889 | -4.912 | -140 |
| -130 | -4.410 | -4.437 | -4.463 | -4.489 | -4.515 | -4.541 | -4.567 | -4.593 | -4.618 | -4.644 | -4.669 | -130 |
| -120 | -4.138 | -4.166 | -4.193 | -4.221 | -4.248 | -4.276 | -4.303 | -4.330 | -4.357 | -4.384 | -4.410 | -120 |
| -110 | -3.852 | -3.881 | -3.910 | -3.939 | -3.968 | -3.997 | -4.025 | -4.053 | -4.082 | -4.110 | -4.138 | -110 |
| -100 | -3.553 | -3.584 | -3.614 | -3.644 | -3.674 | -3.704 | -3.734 | -3.764 | -3.793 | -3.823 | -3.852 | -100 |
| -90 | -3.242 | -3.274 | -3.305 | -3.337 | -3.368 | -3.399 | -3.430 | -3.461 | -3.492 | -3.523 | -3.553 | -90 |
| -80 | -2.920 | -2.953 | -2.985 | -3.018 | -3.050 | -3.082 | -3.115 | -3.147 | -3.179 | -3.211 | -3.242 | -80 |
| -70 | -2.586 | -2.620 | -2.654 | -2.687 | -2.721 | -2.754 | -2.788 | -2.821 | -2.854 | -2.887 | -2.920 | -70 |
| -60 | -2.243 | -2.277 | -2.312 | -2.347 | -2.381 | -2.416 | -2.450 | -2.484 | -2.518 | -2.552 | -2.586 | -60 |
| -50 | -1.889 | -1.925 | -1.961 | -1.996 | -2.032 | -2.067 | -2.102 | -2.137 | -2.173 | -2.208 | -2.243 | -50 |
| -40 | -1.527 | -1.563 | -1.600 | -1.636 | -1.673 | -1.709 | -1.745 | -1.781 | -1.817 | -1.853 | -1.889 | -40 |
| -30 | -1.156 | -1.193 | -1.231 | -1.268 | -1.305 | -1.342 | -1.379 | -1.416 | -1.453 | -1.490 | -1.527 | -30 |
| -20 | -0.777 | -0.816 | -0.854 | -0.892 | -0.930 | -0.968 | -1.005 | -1.043 | -1.081 | -1.118 | -1.156 | -20 |
| -10 | -0.392 | -0.431 | -0.469 | -0.508 | -0.547 | -0.585 | -0.624 | -0.662 | -0.701 | -0.739 | -0.777 | -10 |
| 0 | 0.000 | -0.039 | -0.079 | -0.118 | -0.157 | -0.197 | -0.236 | -0.275 | -0.314 | -0.353 | -0.392 | 0 |
| 10 | 0.397 | 0.437 | 0.477 | 0.517 | 0.557 | 0.597 | 0.637 | 0.677 | 0.718 | 0.758 | 0.798 | 10 |
| 20 | 0.798 | 0.838 | 0.879 | 0.919 | 0.960 | 1.000 | 1.041 | 1.081 | 1.122 | 1.162 | 1.203 | 20 |
| 30 | 1.203 | 1.244 | 1.285 | 1.325 | 1.366 | 1.407 | 1.448 | 1.489 | 1.529 | 1.570 | 1.611 | 30 |
| 40 | 1.611 | 1.652 | 1.693 | 1.734 | 1.776 | 1.817 | 1.858 | 1.899 | 1.940 | 1.981 | 2.022 | 40 |
| 50 | 2.022 | 2.064 | 2.105 | 2.146 | 2.188 | 2.229 | 2.270 | 2.312 | 2.353 | 2.394 | 2.436 | 50 |
| 60 | 2.436 | 2.477 | 2.519 | 2.560 | 2.601 | 2.643 | 2.684 | 2.726 | 2.767 | 2.809 | 2.850 | 60 |
| 70 | 2.850 | 2.892 | 2.933 | 2.975 | 3.016 | 3.058 | 3.100 | 3.141 | 3.183 | 3.224 | 3.266 | 70 |
| 80 | 3.266 | 3.307 | 3.349 | 3.390 | 3.432 | 3.473 | 3.515 | 3.556 | 3.598 | 3.639 | 3.681 | 80 |
| 90 | 3.681 | 3.722 | 3.764 | 3.805 | 3.847 | 3.888 | 3.930 | 3.971 | 4.012 | 4.054 | 4.095 | 90 |
| 100 | 4.095 | 4.137 | 4.178 | 4.219 | 4.261 | 4.302 | 4.343 | 4.384 | 4.426 | 4.467 | 4.508 | 100 |
| 110 | 4.508 | 4.549 | 4.590 | 4.632 | 4.673 | 4.714 | 4.755 | 4.796 | 4.837 | 4.878 | 4.919 | 110 |
| 120 | 4.919 | 4.960 | 5.001 | 5.042 | 5.083 | 5.124 | 5.164 | 5.205 | 5.246 | 5.287 | 5.327 | 120 |
| 130 | 5.327 | 5.368 | 5.409 | 5.450 | 5.490 | 5.531 | 5.571 | 5.612 | 5.652 | 5.693 | 5.733 | 130 |
| 140 | 5.733 | 5.774 | 5.814 | 5.955 | 5.985 | 5.936 | 5.976 | 6.016 | 6.057 | 6.097 | 6.137 | 140 |
| 150 | 6.137 | 6.177 | 6.218 | 6.258 | 6.298 | 6.338 | 6.378 | 6.419 | 6.459 | 6.499 | 6.539 | 150 |
| 160 | 6.539 | 6.579 | 6.619 | 6.659 | 6.699 | 6.739 | 6.779 | 6.819 | 6.859 | 6.899 | 6.939 | 160 |
| 170 | 6.939 | 6.979 | 7.019 | 7.059 | 7.099 | 7.139 | 7.179 | 7.219 | 7.259 | 7.299 | 7.338 | 170 |
| 180 | 7.338 | 7.378 | 7.418 | 7.458 | 7.498 | 7.538 | 7.578 | 7.618 | 7.658 | 7.697 | 7.737 | 180 |
| 190 | 7.737 | 7.777 | 7.817 | 7.857 | 7.897 | 7.937 | 7.977 | 8.017 | 8.057 | 8.097 | 8.137 | 190 |
| 200 | 8.137 | 8.177 | 8.216 | 8.256 | 8.296 | 8.336 | 8.376 | 8.416 | 8.456 | 8.497 | 8.537 | 200 |
| 210 | 8.537 | 8.577 | 8.617 | 8.657 | 8.697 | 8.737 | 8.777 | 8.817 | 8.857 | 8.898 | 8.938 | 210 |
| 220 | 8.938 | 8.978 | 9.018 | 9.058 | 9.099 | 9.139 | 9.179 | 9.220 | 9.260 | 9.300 | 9.341 | 220 |
| 230 | 9.341 | 9.381 | 9.421 | 9.462 | 9.502 | 9.543 | 9.583 | 9.624 | 9.664 | 9.705 | 9.745 | 230 |
| 240 | 9.745 | 9.786 | 9.826 | 9.867 | 9.907 | 9.948 | 9.989 | 10.029 | 10.070 | 10.111 | 10.151 | 240 |
| 250 | 10.151 | 10.192 | 10.233 | 10.274 | 10.315 | 10.355 | 10.396 | 10.437 | 10.478 | 10.519 | 10.560 | 250 |
| 260 | 10.560 | 10.600 | 10.641 | 10.682 | 10.723 | 10.764 | 10.805 | 10.846 | 10.887 | 10.928 | 10.969 | 260 |
| 270 | 10.969 | 11.010 | 11.051 | 11.093 | 11.134 | 11.175 | 11.216 | 11.257 | 11.298 | 11.339 | 11.381 | 270 |
| 280 | 11.381 | 11.422 | 11.463 | 11.504 | 11.546 | 11.587 | 11.628 | 11.669 | 11.711 | 11.752 | 11.793 | 280 |
| 290 | 11.793 | 11.835 | 11.876 | 11.918 | 11.959 | 12.000 | 12.042 | 12.083 | 12.125 | 12.166 | 12.207 | 290 |
| 300 | 12.207 | 12.249 | 12.290 | 12.332 | 12.373 | 12.415 | 12.456 | 12.498 | 12.539 | 12.581 | 12.623 | 300 |
| 310 | 12.623 | 12.664 | 12.706 | 12.747 | 12.789 | 12.831 | 12.872 | 12.914 | 12.955 | 12.997 | 13.039 | 310 |
| 320 | 13.039 | 13.080 | 13.122 | 13.164 | 13.205 | 13.247 | 13.289 | 13.331 | 13.372 | 13.414 | 13.456 | 320 |
| 330 | 13.456 | 13.497 | 13.539 | 13.581 | 13.623 | 13.665 | 13.706 | 13.748 | 13.790 | 13.832 | 13.874 | 330 |
| 340 | 13.874 | 13.915 | 13.957 | 13.999 | 14.041 | 14.083 | 14.125 | 14.167 | 14.208 | 14.250 | 14.292 | 340 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 14 (Continued)

TEMPERATURE-EMF FOR TYPE K THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68) REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 350 | 14.292 | 14.334 | 14.376 | 14.418 | 14.460 | 14.502 | 14.544 | 14.586 | 14.628 | 14.670 | 14.712 | 350 |
| 360 | 14.712 | 14.754 | 14.796 | 14.838 | 14.880 | 14.922 | 14.964 | 15.006 | 15.048 | 15.090 | 15.132 | 360 |
| 370 | 15.132 | 15.174 | 15.216 | 15.258 | 15.300 | 15.342 | 15.384 | 15.426 | 15.468 | 15.510 | 15.552 | 370 |
| 380 | 15.552 | 15.594 | 15.636 | 15.679 | 15.721 | 15.763 | 15.805 | 15.847 | 15.889 | 15.931 | 15.974 | 380 |
| 390 | 15.974 | 16.016 | 16.058 | 16.100 | 16.142 | 16.184 | 16.227 | 16.269 | 16.311 | 16.353 | 16.395 | 390 |
| 400 | 16.395 | 16.438 | 16.480 | 16.522 | 16.564 | 16.607 | 16.649 | 16.691 | 16.733 | 16.776 | 16.818 | 400 |
| 410 | 16.818 | 16.860 | 16.902 | 16.945 | 16.987 | 17.029 | 17.072 | 17.114 | 17.156 | 17.199 | 17.241 | 410 |
| 420 | 17.241 | 17.283 | 17.326 | 17.368 | 17.410 | 17.453 | 17.495 | 17.537 | 17.580 | 17.622 | 17.664 | 420 |
| 430 | 17.664 | 17.707 | 17.749 | 17.792 | 17.834 | 17.876 | 17.919 | 17.961 | 18.004 | 18.046 | 18.088 | 430 |
| 440 | 18.088 | 18.131 | 18.173 | 18.216 | 18.258 | 18.301 | 18.343 | 18.385 | 18.428 | 18.470 | 18.513 | 440 |
| 450 | 18.513 | 18.555 | 18.598 | 18.640 | 18.683 | 18.725 | 18.768 | 18.810 | 18.853 | 18.895 | 18.938 | 450 |
| 460 | 18.938 | 18.980 | 19.023 | 19.065 | 19.108 | 19.150 | 19.193 | 19.235 | 19.278 | 19.320 | 19.363 | 460 |
| 470 | 19.363 | 19.405 | 19.448 | 19.490 | 19.533 | 19.576 | 19.618 | 19.661 | 19.703 | 19.746 | 19.788 | 470 |
| 480 | 19.788 | 19.831 | 19.873 | 19.916 | 19.959 | 20.001 | 20.044 | 20.086 | 20.129 | 20.172 | 20.214 | 480 |
| 490 | 20.214 | 20.257 | 20.299 | 20.342 | 20.385 | 20.427 | 20.470 | 20.512 | 20.555 | 20.598 | 20.640 | 490 |
| 500 | 20.640 | 20.683 | 20.725 | 20.768 | 20.811 | 20.853 | 20.896 | 20.938 | 20.981 | 21.024 | 21.066 | 500 |
| 510 | 21.066 | 21.109 | 21.152 | 21.194 | 21.237 | 21.280 | 21.322 | 21.365 | 21.407 | 21.450 | 21.493 | 510 |
| 520 | 21.493 | 21.535 | 21.578 | 21.621 | 21.663 | 21.706 | 21.749 | 21.791 | 21.834 | 21.876 | 21.919 | 520 |
| 530 | 21.919 | 21.962 | 22.004 | 22.047 | 22.090 | 22.132 | 22.175 | 22.218 | 22.260 | 22.303 | 22.346 | 530 |
| 540 | 22.346 | 22.388 | 22.431 | 22.473 | 22.516 | 22.559 | 22.601 | 22.644 | 22.687 | 22.729 | 22.772 | 540 |
| 550 | 22.772 | 22.815 | 22.857 | 22.900 | 22.942 | 22.985 | 23.028 | 23.070 | 23.113 | 23.156 | 23.198 | 550 |
| 560 | 23.198 | 23.241 | 23.284 | 23.326 | 23.369 | 23.411 | 23.454 | 23.497 | 23.539 | 23.582 | 23.624 | 560 |
| 570 | 23.624 | 23.667 | 23.710 | 23.752 | 23.795 | 23.837 | 23.880 | 23.923 | 23.965 | 24.008 | 24.050 | 570 |
| 580 | 24.050 | 24.093 | 24.136 | 24.178 | 24.221 | 24.263 | 24.306 | 24.348 | 24.391 | 24.434 | 24.476 | 580 |
| 590 | 24.476 | 24.519 | 24.561 | 24.604 | 24.646 | 24.689 | 24.731 | 24.774 | 24.817 | 24.859 | 24.902 | 590 |
| 600 | 24.902 | 24.944 | 24.987 | 25.029 | 25.072 | 25.114 | 25.157 | 25.199 | 25.242 | 25.284 | 25.327 | 600 |
| 610 | 25.327 | 25.369 | 25.412 | 25.454 | 25.497 | 25.539 | 25.582 | 25.624 | 25.666 | 25.709 | 25.751 | 610 |
| 620 | 25.751 | 25.794 | 25.836 | 25.879 | 25.921 | 25.964 | 26.006 | 26.048 | 26.091 | 26.133 | 26.176 | 620 |
| 630 | 26.176 | 26.218 | 26.260 | 26.303 | 26.345 | 26.387 | 26.430 | 26.472 | 26.515 | 26.557 | 26.599 | 630 |
| 640 | 26.599 | 26.642 | 26.684 | 26.726 | 26.769 | 26.811 | 26.853 | 26.896 | 26.938 | 26.980 | 27.022 | 640 |
| 650 | 27.022 | 27.065 | 27.107 | 27.149 | 27.192 | 27.234 | 27.276 | 27.318 | 27.361 | 27.403 | 27.445 | 650 |
| 660 | 27.445 | 27.487 | 27.529 | 27.572 | 27.614 | 27.656 | 27.698 | 27.740 | 27.783 | 27.825 | 27.867 | 660 |
| 670 | 27.867 | 27.909 | 27.951 | 27.993 | 28.035 | 28.078 | 28.120 | 28.162 | 28.204 | 28.246 | 28.288 | 670 |
| 680 | 28.288 | 28.330 | 28.372 | 28.414 | 28.456 | 28.498 | 28.540 | 28.583 | 28.625 | 28.667 | 28.709 | 680 |
| 690 | 28.709 | 28.751 | 28.793 | 28.835 | 28.877 | 28.919 | 28.961 | 29.002 | 29.044 | 29.086 | 29.128 | 690 |
| 700 | 29.128 | 29.170 | 29.212 | 29.254 | 29.296 | 29.338 | 29.380 | 29.422 | 29.464 | 29.505 | 29.547 | 700 |
| 710 | 29.547 | 29.589 | 29.631 | 29.673 | 29.715 | 29.756 | 29.798 | 29.840 | 29.882 | 29.924 | 29.965 | 710 |
| 720 | 29.965 | 30.007 | 30.049 | 30.091 | 30.132 | 30.174 | 30.216 | 30.257 | 30.299 | 30.341 | 30.383 | 720 |
| 730 | 30.383 | 30.424 | 30.466 | 30.508 | 30.549 | 30.591 | 30.632 | 30.674 | 30.716 | 30.757 | 30.799 | 730 |
| 740 | 30.799 | 30.840 | 30.882 | 30.924 | 30.965 | 31.007 | 31.048 | 31.090 | 31.131 | 31.173 | 31.214 | 740 |
| 750 | 31.214 | 31.256 | 31.297 | 31.339 | 31.380 | 31.422 | 31.463 | 31.504 | 31.546 | 31.587 | 31.629 | 750 |
| 760 | 31.629 | 31.670 | 31.712 | 31.753 | 31.794 | 31.836 | 31.877 | 31.918 | 31.960 | 32.001 | 32.042 | 760 |
| 770 | 32.042 | 32.084 | 32.125 | 32.166 | 32.207 | 32.249 | 32.290 | 32.331 | 32.372 | 32.414 | 32.455 | 770 |
| 780 | 32.455 | 32.496 | 32.537 | 32.578 | 32.619 | 32.661 | 32.702 | 32.743 | 32.784 | 32.825 | 32.866 | 780 |
| 790 | 32.866 | 32.907 | 32.948 | 32.990 | 33.031 | 33.072 | 33.113 | 33.154 | 33.195 | 33.236 | 33.277 | 790 |
| 800 | 33.277 | 33.318 | 33.359 | 33.400 | 33.441 | 33.482 | 33.523 | 33.564 | 33.604 | 33.645 | 33.686 | 800 |
| 810 | 33.686 | 33.727 | 33.768 | 33.809 | 33.850 | 33.891 | 33.931 | 33.972 | 34.013 | 34.054 | 34.095 | 810 |
| 820 | 34.095 | 34.136 | 34.176 | 34.217 | 34.258 | 34.299 | 34.339 | 34.380 | 34.421 | 34.461 | 34.502 | 820 |
| 830 | 34.502 | 34.543 | 34.583 | 34.624 | 34.665 | 34.705 | 34.746 | 34.787 | 34.827 | 34.868 | 34.909 | 830 |
| 840 | 34.909 | 34.949 | 34.990 | 35.030 | 35.071 | 35.111 | 35.152 | 35.192 | 35.233 | 35.273 | 35.314 | 840 |
| 850 | 35.314 | 35.354 | 35.395 | 35.435 | 35.476 | 35.516 | 35.557 | 35.597 | 35.637 | 35.678 | 35.718 | 850 |
| 860 | 35.718 | 35.758 | 35.799 | 35.839 | 35.880 | 35.920 | 35.960 | 36.000 | 36.041 | 36.081 | 36.121 | 860 |
| 870 | 36.121 | 36.162 | 36.202 | 36.242 | 36.282 | 36.323 | 36.363 | 36.403 | 36.443 | 36.483 | 36.524 | 870 |
| 880 | 36.524 | 36.564 | 36.604 | 36.644 | 36.684 | 36.724 | 36.764 | 36.804 | 36.844 | 36.885 | 36.925 | 880 |
| 890 | 36.925 | 36.965 | 37.005 | 37.045 | 37.085 | 37.125 | 37.165 | 37.205 | 37.245 | 37.285 | 37.325 | 890 |
| 900 | 37.325 | 37.365 | 37.405 | 37.445 | 37.484 | 37.524 | 37.564 | 37.604 | 37.644 | 37.684 | 37.724 | 900 |
| 910 | 37.724 | 37.764 | 37.803 | 37.843 | 37.883 | 37.923 | 37.963 | 38.002 | 38.042 | 38.082 | 38.122 | 910 |
| 920 | 38.122 | 38.162 | 38.201 | 38.241 | 38.281 | 38.320 | 38.360 | 38.400 | 38.439 | 38.479 | 38.519 | 920 |
| 930 | 38.519 | 38.558 | 38.598 | 38.638 | 38.677 | 38.717 | 38.756 | 38.796 | 38.836 | 38.875 | 38.915 | 930 |
| 940 | 38.915 | 38.954 | 38.994 | 39.033 | 39.073 | 39.112 | 39.152 | 39.191 | 39.231 | 39.270 | 39.310 | 940 |
| 950 | 39.310 | 39.349 | 39.388 | 39.428 | 39.467 | 39.507 | 39.546 | 39.585 | 39.625 | 39.664 | 39.703 | 950 |
| 960 | 39.703 | 39.743 | 39.782 | 39.821 | 39.861 | 39.900 | 39.939 | 39.979 | 40.018 | 40.057 | 40.096 | 960 |
| 970 | 40.096 | 40.136 | 40.175 | 40.214 | 40.253 | 40.292 | 40.332 | 40.371 | 40.410 | 40.449 | 40.488 | 970 |
| 980 | 40.488 | 40.527 | 40.566 | 40.605 | 40.645 | 40.684 | 40.723 | 40.762 | 40.801 | 40.840 | 40.879 | 980 |
| 990 | 40.879 | 40.918 | 40.957 | 40.996 | 41.035 | 41.074 | 41.113 | 41.152 | 41.191 | 41.230 | 41.269 | 990 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 14 (Continued)

TEMPERATURE-EMF FOR TYPE K THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 1000 | 41.269 | 41.308 | 41.347 | 41.385 | 41.424 | 41.463 | 41.502 | 41.541 | 41.580 | 41.619 | 41.657 | 1000 |
| 1010 | 41.657 | 41.696 | 41.735 | 41.774 | 41.813 | 41.851 | 41.890 | 41.929 | 41.968 | 42.006 | 42.045 | 1010 |
| 1020 | 42.045 | 42.084 | 42.123 | 42.161 | 42.200 | 42.239 | 42.277 | 42.316 | 42.355 | 42.393 | 42.432 | 1020 |
| 1030 | 42.432 | 42.470 | 42.509 | 42.548 | 42.586 | 42.625 | 42.663 | 42.702 | 42.740 | 42.779 | 42.817 | 1030 |
| 1040 | 42.817 | 42.856 | 42.894 | 42.933 | 42.971 | 43.010 | 43.048 | 43.087 | 43.125 | 43.164 | 43.202 | 1040 |
| 1050 | 43.202 | 43.240 | 43.279 | 43.317 | 43.356 | 43.394 | 43.432 | 43.471 | 43.509 | 43.547 | 43.585 | 1050 |
| 1060 | 43.585 | 43.624 | 43.662 | 43.700 | 43.739 | 43.777 | 43.815 | 43.853 | 43.891 | 43.930 | 43.968 | 1060 |
| 1070 | 43.968 | 44.006 | 44.044 | 44.082 | 44.121 | 44.159 | 44.197 | 44.235 | 44.273 | 44.311 | 44.349 | 1070 |
| 1080 | 44.349 | 44.387 | 44.425 | 44.463 | 44.501 | 44.539 | 44.577 | 44.615 | 44.653 | 44.691 | 44.729 | 1080 |
| 1090 | 44.729 | 44.767 | 44.805 | 44.843 | 44.881 | 44.919 | 44.957 | 44.995 | 45.033 | 45.070 | 45.108 | 1090 |
| 1100 | 45.108 | 45.146 | 45.184 | 45.222 | 45.260 | 45.297 | 45.335 | 45.373 | 45.411 | 45.448 | 45.486 | 1100 |
| 1110 | 45.486 | 45.524 | 45.561 | 45.599 | 45.637 | 45.675 | 45.712 | 45.750 | 45.787 | 45.825 | 45.863 | 1110 |
| 1120 | 45.863 | 45.900 | 45.938 | 45.975 | 46.013 | 46.050 | 46.088 | 46.126 | 46.163 | 46.201 | 46.238 | 1120 |
| 1130 | 46.238 | 46.275 | 46.313 | 46.350 | 46.388 | 46.425 | 46.463 | 46.500 | 46.537 | 46.575 | 46.612 | 1130 |
| 1140 | 46.612 | 46.649 | 46.687 | 46.724 | 46.761 | 46.799 | 46.836 | 46.873 | 46.910 | 46.948 | 46.985 | 1140 |
| 1150 | 46.985 | 47.022 | 47.059 | 47.096 | 47.134 | 47.171 | 47.208 | 47.245 | 47.282 | 47.319 | 47.356 | 1150 |
| 1160 | 47.356 | 47.393 | 47.430 | 47.468 | 47.505 | 47.542 | 47.579 | 47.616 | 47.653 | 47.689 | 47.726 | 1160 |
| 1170 | 47.726 | 47.763 | 47.800 | 47.837 | 47.874 | 47.911 | 47.948 | 47.985 | 48.021 | 48.058 | 48.095 | 1170 |
| 1180 | 48.095 | 48.132 | 48.169 | 48.205 | 48.242 | 48.279 | 48.316 | 48.352 | 48.389 | 48.426 | 48.462 | 1180 |
| 1190 | 48.462 | 48.499 | 48.536 | 48.572 | 48.609 | 48.645 | 48.682 | 48.718 | 48.755 | 48.792 | 48.828 | 1190 |
| 1200 | 48.828 | 48.865 | 48.901 | 48.937 | 48.974 | 49.010 | 49.047 | 49.083 | 49.120 | 49.156 | 49.192 | 1200 |
| 1210 | 49.192 | 49.229 | 49.265 | 49.301 | 49.338 | 49.374 | 49.410 | 49.446 | 49.483 | 49.519 | 49.555 | 1210 |
| 1220 | 49.555 | 49.591 | 49.627 | 49.663 | 49.700 | 49.736 | 49.772 | 49.808 | 49.844 | 49.880 | 49.916 | 1220 |
| 1230 | 49.916 | 49.952 | 49.988 | 50.024 | 50.060 | 50.096 | 50.132 | 50.168 | 50.204 | 50.240 | 50.276 | 1230 |
| 1240 | 50.276 | 50.311 | 50.347 | 50.383 | 50.419 | 50.455 | 50.491 | 50.526 | 50.562 | 50.598 | 50.633 | 1240 |
| 1250 | 50.633 | 50.669 | 50.705 | 50.741 | 50.776 | 50.812 | 50.847 | 50.883 | 50.919 | 50.954 | 50.990 | 1250 |
| 1260 | 50.990 | 51.025 | 51.061 | 51.096 | 51.132 | 51.167 | 51.203 | 51.238 | 51.274 | 51.309 | 51.344 | 1260 |
| 1270 | 51.344 | 51.380 | 51.415 | 51.450 | 51.486 | 51.521 | 51.556 | 51.592 | 51.627 | 51.662 | 51.697 | 1270 |
| 1280 | 51.697 | 51.733 | 51.768 | 51.803 | 51.838 | 51.873 | 51.908 | 51.943 | 51.979 | 52.014 | 52.049 | 1280 |
| 1290 | 52.049 | 52.084 | 52.119 | 52.154 | 52.189 | 52.224 | 52.259 | 52.294 | 52.329 | 52.364 | 52.398 | 1290 |
| 1300 | 52.398 | 52.433 | 52.468 | 52.503 | 52.538 | 52.573 | 52.608 | 52.642 | 52.677 | 52.712 | 52.747 | 1300 |
| 1310 | 52.747 | 52.781 | 52.816 | 52.851 | 52.886 | 52.920 | 52.955 | 52.989 | 53.024 | 53.059 | 53.093 | 1310 |
| 1320 | 53.093 | 53.128 | 53.162 | 53.197 | 53.232 | 53.266 | 53.301 | 53.335 | 53.370 | 53.404 | 53.439 | 1320 |
| 1330 | 53.439 | 53.473 | 53.507 | 53.542 | 53.576 | 53.611 | 53.645 | 53.679 | 53.714 | 53.748 | 53.782 | 1330 |
| 1340 | 53.782 | 53.817 | 53.851 | 53.885 | 53.920 | 53.954 | 53.988 | 54.022 | 54.057 | 54.091 | 54.125 | 1340 |
| 1350 | 54.125 | 54.159 | 54.193 | 54.228 | 54.262 | 54.296 | 54.330 | 54.364 | 54.398 | 54.432 | 54.466 | 1350 |
| 1360 | 54.466 | 54.501 | 54.535 | 54.569 | 54.603 | 54.637 | 54.671 | 54.705 | 54.739 | 54.773 | 54.807 | 1360 |
| 1370 | 54.807 | 54.841 | 54.875 | | | | | | | | | 1370 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 15
TEMPERATURE-EMF FOR TYPE R THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68) **REFERENCE JUNCTIONS AT 0°C**

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| -50 | -0.226 | | | | | | | | | | | -50 |
| -40 | -0.188 | -0.192 | -0.196 | -0.200 | -0.204 | -0.207 | -0.211 | -0.215 | -0.219 | -0.223 | -0.226 | -40 |
| -30 | -0.145 | -0.150 | -0.154 | -0.158 | -0.163 | -0.167 | -0.171 | -0.175 | -0.180 | -0.184 | -0.188 | -30 |
| -20 | -0.100 | -0.105 | -0.109 | -0.114 | -0.119 | -0.123 | -0.128 | -0.132 | -0.137 | -0.141 | -0.145 | -20 |
| -10 | -0.051 | -0.056 | -0.061 | -0.066 | -0.071 | -0.076 | -0.081 | -0.086 | -0.091 | -0.095 | -0.100 | -10 |
| 0 | 0.000 | -0.005 | -0.011 | -0.016 | -0.021 | -0.026 | -0.031 | -0.036 | -0.041 | -0.046 | -0.051 | 0 |
| 10 | 0.054 | 0.060 | 0.065 | 0.071 | 0.077 | 0.082 | 0.088 | 0.094 | 0.100 | 0.105 | 0.111 | 10 |
| 20 | 0.111 | 0.117 | 0.123 | 0.129 | 0.135 | 0.141 | 0.147 | 0.152 | 0.158 | 0.165 | 0.171 | 20 |
| 30 | 0.171 | 0.177 | 0.183 | 0.189 | 0.195 | 0.201 | 0.207 | 0.214 | 0.220 | 0.226 | 0.232 | 30 |
| 40 | 0.232 | 0.239 | 0.245 | 0.251 | 0.258 | 0.264 | 0.271 | 0.277 | 0.283 | 0.290 | 0.296 | 40 |
| 50 | 0.296 | 0.303 | 0.310 | 0.316 | 0.323 | 0.329 | 0.336 | 0.343 | 0.349 | 0.356 | 0.363 | 50 |
| 60 | 0.363 | 0.369 | 0.376 | 0.383 | 0.390 | 0.397 | 0.403 | 0.410 | 0.417 | 0.424 | 0.431 | 60 |
| 70 | 0.431 | 0.438 | 0.445 | 0.452 | 0.459 | 0.466 | 0.473 | 0.480 | 0.487 | 0.494 | 0.501 | 70 |
| 80 | 0.501 | 0.508 | 0.515 | 0.523 | 0.530 | 0.537 | 0.544 | 0.552 | 0.559 | 0.566 | 0.573 | 80 |
| 90 | 0.573 | 0.581 | 0.588 | 0.595 | 0.603 | 0.610 | 0.617 | 0.625 | 0.632 | 0.640 | 0.647 | 90 |
| 100 | 0.647 | 0.655 | 0.662 | 0.670 | 0.677 | 0.685 | 0.692 | 0.700 | 0.708 | 0.715 | 0.723 | 100 |
| 110 | 0.723 | 0.730 | 0.738 | 0.746 | 0.754 | 0.761 | 0.769 | 0.777 | 0.784 | 0.792 | 0.800 | 110 |
| 120 | 0.800 | 0.808 | 0.816 | 0.824 | 0.831 | 0.839 | 0.847 | 0.855 | 0.863 | 0.871 | 0.879 | 120 |
| 130 | 0.879 | 0.887 | 0.895 | 0.903 | 0.911 | 0.919 | 0.927 | 0.935 | 0.943 | 0.951 | 0.959 | 130 |
| 140 | 0.959 | 0.967 | 0.975 | 0.983 | 0.992 | 1.000 | 1.008 | 1.016 | 1.024 | 1.032 | 1.041 | 140 |
| 150 | 1.041 | 1.049 | 1.057 | 1.065 | 1.074 | 1.082 | 1.090 | 1.099 | 1.107 | 1.115 | 1.124 | 150 |
| 160 | 1.124 | 1.132 | 1.140 | 1.149 | 1.157 | 1.166 | 1.174 | 1.183 | 1.191 | 1.200 | 1.208 | 160 |
| 170 | 1.208 | 1.217 | 1.225 | 1.234 | 1.242 | 1.251 | 1.259 | 1.268 | 1.276 | 1.285 | 1.294 | 170 |
| 180 | 1.294 | 1.302 | 1.311 | 1.319 | 1.328 | 1.337 | 1.345 | 1.354 | 1.363 | 1.372 | 1.380 | 180 |
| 190 | 1.380 | 1.389 | 1.398 | 1.407 | 1.415 | 1.424 | 1.433 | 1.442 | 1.450 | 1.459 | 1.468 | 190 |
| 200 | 1.468 | 1.477 | 1.486 | 1.495 | 1.504 | 1.512 | 1.521 | 1.530 | 1.539 | 1.548 | 1.557 | 200 |
| 210 | 1.557 | 1.566 | 1.575 | 1.584 | 1.593 | 1.602 | 1.611 | 1.620 | 1.629 | 1.638 | 1.647 | 210 |
| 220 | 1.647 | 1.656 | 1.665 | 1.674 | 1.683 | 1.692 | 1.702 | 1.711 | 1.720 | 1.729 | 1.738 | 220 |
| 230 | 1.738 | 1.747 | 1.756 | 1.766 | 1.775 | 1.784 | 1.793 | 1.802 | 1.812 | 1.821 | 1.830 | 230 |
| 240 | 1.830 | 1.839 | 1.849 | 1.858 | 1.867 | 1.876 | 1.886 | 1.895 | 1.904 | 1.914 | 1.923 | 240 |
| 250 | 1.923 | 1.932 | 1.942 | 1.951 | 1.960 | 1.970 | 1.979 | 1.988 | 1.998 | 2.007 | 2.017 | 250 |
| 260 | 2.017 | 2.026 | 2.036 | 2.045 | 2.054 | 2.064 | 2.073 | 2.083 | 2.092 | 2.102 | 2.111 | 260 |
| 270 | 2.111 | 2.121 | 2.130 | 2.140 | 2.149 | 2.159 | 2.169 | 2.178 | 2.188 | 2.197 | 2.207 | 270 |
| 280 | 2.207 | 2.216 | 2.226 | 2.236 | 2.245 | 2.255 | 2.264 | 2.274 | 2.284 | 2.293 | 2.303 | 280 |
| 290 | 2.303 | 2.313 | 2.322 | 2.332 | 2.342 | 2.351 | 2.361 | 2.371 | 2.381 | 2.390 | 2.400 | 290 |
| 300 | 2.400 | 2.410 | 2.420 | 2.429 | 2.439 | 2.449 | 2.459 | 2.468 | 2.478 | 2.488 | 2.498 | 300 |
| 310 | 2.498 | 2.508 | 2.517 | 2.527 | 2.537 | 2.547 | 2.557 | 2.567 | 2.577 | 2.586 | 2.596 | 310 |
| 320 | 2.596 | 2.606 | 2.616 | 2.626 | 2.636 | 2.646 | 2.656 | 2.666 | 2.676 | 2.685 | 2.695 | 320 |
| 330 | 2.695 | 2.705 | 2.715 | 2.725 | 2.735 | 2.745 | 2.755 | 2.765 | 2.775 | 2.785 | 2.795 | 330 |
| 340 | 2.795 | 2.805 | 2.815 | 2.825 | 2.835 | 2.845 | 2.855 | 2.866 | 2.876 | 2.886 | 2.896 | 340 |
| 350 | 2.896 | 2.906 | 2.916 | 2.926 | 2.936 | 2.946 | 2.956 | 2.966 | 2.977 | 2.987 | 2.997 | 350 |
| 360 | 2.997 | 3.007 | 3.017 | 3.027 | 3.037 | 3.048 | 3.058 | 3.068 | 3.078 | 3.088 | 3.099 | 360 |
| 370 | 3.099 | 3.109 | 3.119 | 3.129 | 3.139 | 3.150 | 3.160 | 3.170 | 3.180 | 3.191 | 3.201 | 370 |
| 380 | 3.201 | 3.211 | 3.221 | 3.232 | 3.242 | 3.252 | 3.263 | 3.273 | 3.283 | 3.293 | 3.304 | 380 |
| 390 | 3.304 | 3.314 | 3.324 | 3.335 | 3.345 | 3.355 | 3.366 | 3.376 | 3.386 | 3.397 | 3.407 | 390 |
| 400 | 3.407 | 3.418 | 3.428 | 3.438 | 3.449 | 3.459 | 3.470 | 3.480 | 3.490 | 3.501 | 3.511 | 400 |
| 410 | 3.511 | 3.522 | 3.532 | 3.542 | 3.553 | 3.563 | 3.574 | 3.584 | 3.595 | 3.605 | 3.616 | 410 |
| 420 | 3.616 | 3.626 | 3.637 | 3.647 | 3.658 | 3.668 | 3.679 | 3.689 | 3.700 | 3.710 | 3.721 | 420 |
| 430 | 3.721 | 3.731 | 3.742 | 3.752 | 3.763 | 3.774 | 3.784 | 3.795 | 3.805 | 3.816 | 3.826 | 430 |
| 440 | 3.826 | 3.837 | 3.848 | 3.858 | 3.869 | 3.879 | 3.890 | 3.901 | 3.911 | 3.922 | 3.933 | 440 |
| 450 | 3.933 | 3.943 | 3.954 | 3.964 | 3.975 | 3.986 | 3.996 | 4.007 | 4.018 | 4.028 | 4.039 | 450 |
| 460 | 4.039 | 4.050 | 4.061 | 4.071 | 4.082 | 4.093 | 4.103 | 4.114 | 4.125 | 4.136 | 4.146 | 460 |
| 470 | 4.146 | 4.157 | 4.168 | 4.178 | 4.189 | 4.200 | 4.211 | 4.222 | 4.232 | 4.243 | 4.254 | 470 |
| 480 | 4.254 | 4.265 | 4.275 | 4.286 | 4.297 | 4.308 | 4.319 | 4.329 | 4.340 | 4.351 | 4.362 | 480 |
| 490 | 4.362 | 4.373 | 4.384 | 4.394 | 4.405 | 4.416 | 4.427 | 4.438 | 4.449 | 4.460 | 4.471 | 490 |
| 500 | 4.471 | 4.481 | 4.492 | 4.503 | 4.514 | 4.525 | 4.536 | 4.547 | 4.558 | 4.569 | 4.580 | 500 |
| 510 | 4.580 | 4.591 | 4.601 | 4.612 | 4.623 | 4.634 | 4.645 | 4.656 | 4.667 | 4.678 | 4.689 | 510 |
| 520 | 4.689 | 4.700 | 4.711 | 4.722 | 4.733 | 4.744 | 4.755 | 4.766 | 4.777 | 4.788 | 4.799 | 520 |
| 530 | 4.799 | 4.810 | 4.821 | 4.832 | 4.843 | 4.854 | 4.865 | 4.876 | 4.888 | 4.899 | 4.910 | 530 |
| 540 | 4.910 | 4.921 | 4.932 | 4.943 | 4.954 | 4.965 | 4.976 | 4.987 | 4.998 | 5.009 | 5.021 | 540 |
| 550 | 5.021 | 5.032 | 5.043 | 5.054 | 5.065 | 5.076 | 5.087 | 5.099 | 5.110 | 5.121 | 5.132 | 550 |
| 560 | 5.132 | 5.143 | 5.154 | 5.166 | 5.177 | 5.188 | 5.199 | 5.210 | 5.221 | 5.233 | 5.244 | 560 |
| 570 | 5.244 | 5.255 | 5.266 | 5.278 | 5.289 | 5.300 | 5.311 | 5.322 | 5.334 | 5.345 | 5.356 | 570 |
| 580 | 5.356 | 5.367 | 5.379 | 5.390 | 5.401 | 5.413 | 5.424 | 5.435 | 5.446 | 5.458 | 5.469 | 580 |
| 590 | 5.469 | 5.480 | 5.492 | 5.503 | 5.514 | 5.526 | 5.537 | 5.548 | 5.560 | 5.571 | 5.582 | 590 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 15 (Continued)

TEMPERATURE-EMF FOR TYPE R THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 600 | 5.582 | 5.594 | 5.605 | 5.616 | 5.628 | 5.639 | 5.650 | 5.662 | 5.673 | 5.685 | 5.696 | 600 |
| 610 | 5.696 | 5.707 | 5.719 | 5.730 | 5.742 | 5.753 | 5.764 | 5.776 | 5.787 | 5.799 | 5.810 | 610 |
| 620 | 5.810 | 5.821 | 5.833 | 5.844 | 5.856 | 5.867 | 5.879 | 5.890 | 5.902 | 5.913 | 5.925 | 620 |
| 630 | 5.925 | 5.936 | 5.948 | 5.959 | 5.971 | 5.982 | 5.994 | 6.005 | 6.017 | 6.028 | 6.040 | 630 |
| 640 | 6.040 | 6.051 | 6.063 | 6.074 | 6.086 | 6.098 | 6.109 | 6.121 | 6.132 | 6.144 | 6.155 | 640 |
| 650 | 6.155 | 6.167 | 6.179 | 6.190 | 6.202 | 6.213 | 6.225 | 6.237 | 6.248 | 6.260 | 6.272 | 650 |
| 660 | 6.272 | 6.283 | 6.295 | 6.307 | 6.318 | 6.330 | 6.342 | 6.353 | 6.365 | 6.377 | 6.388 | 660 |
| 670 | 6.388 | 6.400 | 6.412 | 6.423 | 6.435 | 6.447 | 6.458 | 6.470 | 6.482 | 6.494 | 6.505 | 670 |
| 680 | 6.505 | 6.517 | 6.529 | 6.541 | 6.552 | 6.564 | 6.576 | 6.588 | 6.599 | 6.611 | 6.623 | 680 |
| 690 | 6.623 | 6.635 | 6.647 | 6.658 | 6.670 | 6.682 | 6.694 | 6.706 | 6.718 | 6.729 | 6.741 | 690 |
| 700 | 6.741 | 6.753 | 6.765 | 6.777 | 6.789 | 6.800 | 6.812 | 6.824 | 6.836 | 6.848 | 6.860 | 700 |
| 710 | 6.860 | 6.872 | 6.884 | 6.895 | 6.907 | 6.919 | 6.931 | 6.943 | 6.955 | 6.967 | 6.979 | 710 |
| 720 | 6.979 | 6.991 | 7.003 | 7.015 | 7.027 | 7.039 | 7.051 | 7.063 | 7.074 | 7.086 | 7.098 | 720 |
| 730 | 7.098 | 7.110 | 7.122 | 7.134 | 7.146 | 7.158 | 7.170 | 7.182 | 7.194 | 7.206 | 7.218 | 730 |
| 740 | 7.218 | 7.231 | 7.243 | 7.255 | 7.267 | 7.279 | 7.291 | 7.303 | 7.315 | 7.327 | 7.339 | 740 |
| 750 | 7.339 | 7.351 | 7.363 | 7.375 | 7.387 | 7.399 | 7.412 | 7.424 | 7.436 | 7.448 | 7.460 | 750 |
| 760 | 7.460 | 7.472 | 7.484 | 7.496 | 7.509 | 7.521 | 7.533 | 7.545 | 7.557 | 7.569 | 7.582 | 760 |
| 770 | 7.582 | 7.594 | 7.606 | 7.618 | 7.630 | 7.642 | 7.655 | 7.667 | 7.679 | 7.691 | 7.703 | 770 |
| 780 | 7.703 | 7.716 | 7.728 | 7.740 | 7.752 | 7.765 | 7.777 | 7.789 | 7.801 | 7.814 | 7.826 | 780 |
| 790 | 7.826 | 7.838 | 7.850 | 7.863 | 7.875 | 7.887 | 7.900 | 7.912 | 7.924 | 7.937 | 7.949 | 790 |
| 800 | 7.949 | 7.961 | 7.973 | 7.986 | 7.998 | 8.010 | 8.023 | 8.035 | 8.047 | 8.060 | 8.072 | 800 |
| 810 | 8.072 | 8.085 | 8.097 | 8.109 | 8.122 | 8.134 | 8.146 | 8.159 | 8.171 | 8.184 | 8.196 | 810 |
| 820 | 8.196 | 8.208 | 8.221 | 8.233 | 8.246 | 8.258 | 8.271 | 8.283 | 8.295 | 8.308 | 8.320 | 820 |
| 830 | 8.320 | 8.333 | 8.345 | 8.358 | 8.370 | 8.383 | 8.395 | 8.408 | 8.420 | 8.433 | 8.445 | 830 |
| 840 | 8.445 | 8.458 | 8.470 | 8.483 | 8.495 | 8.508 | 8.520 | 8.533 | 8.545 | 8.558 | 8.570 | 840 |
| 850 | 8.570 | 8.583 | 8.595 | 8.608 | 8.621 | 8.633 | 8.646 | 8.658 | 8.671 | 8.683 | 8.696 | 850 |
| 860 | 8.696 | 8.709 | 8.721 | 8.734 | 8.746 | 8.759 | 8.772 | 8.784 | 8.797 | 8.810 | 8.822 | 860 |
| 870 | 8.822 | 8.835 | 8.847 | 8.860 | 8.873 | 8.885 | 8.898 | 8.911 | 8.923 | 8.936 | 8.949 | 870 |
| 880 | 8.949 | 8.961 | 8.974 | 8.987 | 9.000 | 9.012 | 9.025 | 9.038 | 9.050 | 9.063 | 9.076 | 880 |
| 890 | 9.076 | 9.089 | 9.101 | 9.114 | 9.127 | 9.140 | 9.152 | 9.165 | 9.178 | 9.191 | 9.203 | 890 |
| 900 | 9.203 | 9.216 | 9.229 | 9.242 | 9.254 | 9.267 | 9.280 | 9.293 | 9.306 | 9.319 | 9.331 | 900 |
| 910 | 9.331 | 9.344 | 9.357 | 9.370 | 9.383 | 9.395 | 9.408 | 9.421 | 9.434 | 9.447 | 9.460 | 910 |
| 920 | 9.460 | 9.473 | 9.485 | 9.498 | 9.511 | 9.524 | 9.537 | 9.550 | 9.563 | 9.576 | 9.589 | 920 |
| 930 | 9.589 | 9.602 | 9.614 | 9.627 | 9.640 | 9.653 | 9.666 | 9.679 | 9.692 | 9.705 | 9.718 | 930 |
| 940 | 9.718 | 9.731 | 9.744 | 9.757 | 9.770 | 9.783 | 9.796 | 9.809 | 9.822 | 9.835 | 9.848 | 940 |
| 950 | 9.848 | 9.861 | 9.874 | 9.887 | 9.900 | 9.913 | 9.926 | 9.939 | 9.952 | 9.965 | 9.978 | 950 |
| 960 | 9.978 | 9.991 | 10.004 | 10.017 | 10.030 | 10.043 | 10.056 | 10.069 | 10.082 | 10.095 | 10.109 | 960 |
| 970 | 10.109 | 10.122 | 10.135 | 10.148 | 10.161 | 10.174 | 10.187 | 10.200 | 10.213 | 10.227 | 10.240 | 970 |
| 980 | 10.240 | 10.253 | 10.266 | 10.279 | 10.292 | 10.305 | 10.319 | 10.332 | 10.345 | 10.358 | 10.371 | 980 |
| 990 | 10.371 | 10.384 | 10.398 | 10.411 | 10.424 | 10.437 | 10.450 | 10.464 | 10.477 | 10.490 | 10.503 | 990 |
| 1000 | 10.503 | 10.516 | 10.530 | 10.543 | 10.556 | 10.569 | 10.583 | 10.596 | 10.609 | 10.622 | 10.636 | 1000 |
| 1010 | 10.636 | 10.649 | 10.662 | 10.675 | 10.689 | 10.702 | 10.715 | 10.729 | 10.742 | 10.755 | 10.768 | 1010 |
| 1020 | 10.768 | 10.782 | 10.795 | 10.808 | 10.822 | 10.835 | 10.848 | 10.862 | 10.875 | 10.888 | 10.902 | 1020 |
| 1030 | 10.902 | 10.915 | 10.928 | 10.942 | 10.955 | 10.968 | 10.982 | 10.995 | 11.009 | 11.022 | 11.035 | 1030 |
| 1040 | 11.035 | 11.049 | 11.062 | 11.076 | 11.089 | 11.102 | 11.116 | 11.129 | 11.143 | 11.156 | 11.170 | 1040 |
| 1050 | 11.170 | 11.183 | 11.196 | 11.210 | 11.223 | 11.237 | 11.250 | 11.264 | 11.277 | 11.291 | 11.304 | 1050 |
| 1060 | 11.304 | 11.318 | 11.331 | 11.345 | 11.358 | 11.372 | 11.385 | 11.399 | 11.412 | 11.426 | 11.439 | 1060 |
| 1070 | 11.439 | 11.453 | 11.466 | 11.480 | 11.493 | 11.507 | 11.520 | 11.534 | 11.547 | 11.561 | 11.574 | 1070 |
| 1080 | 11.574 | 11.588 | 11.602 | 11.615 | 11.629 | 11.642 | 11.656 | 11.669 | 11.683 | 11.697 | 11.710 | 1080 |
| 1090 | 11.710 | 11.724 | 11.737 | 11.751 | 11.765 | 11.778 | 11.792 | 11.805 | 11.819 | 11.833 | 11.846 | 1090 |
| 1100 | 11.846 | 11.860 | 11.874 | 11.887 | 11.901 | 11.914 | 11.928 | 11.942 | 11.955 | 11.969 | 11.983 | 1100 |
| 1110 | 11.983 | 11.996 | 12.010 | 12.024 | 12.037 | 12.051 | 12.065 | 12.078 | 12.092 | 12.106 | 12.119 | 1110 |
| 1120 | 12.119 | 12.133 | 12.147 | 12.161 | 12.174 | 12.188 | 12.202 | 12.215 | 12.229 | 12.243 | 12.257 | 1120 |
| 1130 | 12.257 | 12.270 | 12.284 | 12.298 | 12.311 | 12.325 | 12.339 | 12.353 | 12.366 | 12.380 | 12.394 | 1130 |
| 1140 | 12.394 | 12.408 | 12.421 | 12.435 | 12.449 | 12.463 | 12.476 | 12.490 | 12.504 | 12.518 | 12.532 | 1140 |
| 1150 | 12.532 | 12.545 | 12.559 | 12.573 | 12.587 | 12.600 | 12.614 | 12.628 | 12.642 | 12.656 | 12.669 | 1150 |
| 1160 | 12.669 | 12.683 | 12.697 | 12.711 | 12.725 | 12.739 | 12.752 | 12.766 | 12.780 | 12.794 | 12.808 | 1160 |
| 1170 | 12.808 | 12.822 | 12.835 | 12.849 | 12.863 | 12.877 | 12.891 | 12.905 | 12.918 | 12.932 | 12.946 | 1170 |
| 1180 | 12.946 | 12.960 | 12.974 | 12.988 | 13.002 | 13.016 | 13.029 | 13.043 | 13.057 | 13.071 | 13.085 | 1180 |
| 1190 | 13.085 | 13.099 | 13.113 | 13.127 | 13.140 | 13.154 | 13.168 | 13.182 | 13.196 | 13.210 | 13.224 | 1190 |
| 1200 | 13.224 | 13.238 | 13.252 | 13.266 | 13.280 | 13.293 | 13.307 | 13.321 | 13.335 | 13.349 | 13.363 | 1200 |
| 1210 | 13.363 | 13.377 | 13.391 | 13.405 | 13.419 | 13.433 | 13.447 | 13.461 | 13.475 | 13.489 | 13.502 | 1210 |
| 1220 | 13.502 | 13.516 | 13.530 | 13.544 | 13.558 | 13.572 | 13.586 | 13.600 | 13.614 | 13.628 | 13.642 | 1220 |
| 1230 | 13.642 | 13.656 | 13.670 | 13.684 | 13.698 | 13.712 | 13.726 | 13.740 | 13.754 | 13.768 | 13.782 | 1230 |
| 1240 | 13.782 | 13.796 | 13.810 | 13.824 | 13.838 | 13.852 | 13.866 | 13.880 | 13.894 | 13.908 | 13.922 | 1240 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 15 (Continued)

TEMPERATURE-EMF FOR TYPE R THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68) REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 1250 | 13.922 | 13.936 | 13.950 | 13.964 | 13.978 | 13.992 | 14.006 | 14.020 | 14.034 | 14.048 | 14.062 | 1250 |
| 1260 | 14.062 | 14.076 | 14.090 | 14.104 | 14.118 | 14.132 | 14.146 | 14.160 | 14.174 | 14.188 | 14.202 | 1260 |
| 1270 | 14.202 | 14.216 | 14.230 | 14.244 | 14.258 | 14.272 | 14.286 | 14.301 | 14.315 | 14.329 | 14.343 | 1270 |
| 1280 | 14.343 | 14.357 | 14.371 | 14.385 | 14.399 | 14.413 | 14.427 | 14.441 | 14.455 | 14.469 | 14.483 | 1280 |
| 1290 | 14.483 | 14.497 | 14.511 | 14.525 | 14.539 | 14.554 | 14.568 | 14.582 | 14.596 | 14.610 | 14.624 | 1290 |
| 1300 | 14.624 | 14.638 | 14.652 | 14.666 | 14.680 | 14.694 | 14.708 | 14.722 | 14.737 | 14.751 | 14.765 | 1300 |
| 1310 | 14.765 | 14.779 | 14.793 | 14.807 | 14.821 | 14.835 | 14.849 | 14.863 | 14.877 | 14.891 | 14.906 | 1310 |
| 1320 | 14.906 | 14.920 | 14.934 | 14.948 | 14.962 | 14.976 | 14.990 | 15.004 | 15.018 | 15.032 | 15.047 | 1320 |
| 1330 | 15.047 | 15.061 | 15.075 | 15.089 | 15.103 | 15.117 | 15.131 | 15.145 | 15.159 | 15.173 | 15.188 | 1330 |
| 1340 | 15.188 | 15.202 | 15.216 | 15.230 | 15.244 | 15.258 | 15.272 | 15.286 | 15.300 | 15.315 | 15.329 | 1340 |
| 1350 | 15.329 | 15.343 | 15.357 | 15.371 | 15.385 | 15.399 | 15.413 | 15.427 | 15.442 | 15.456 | 15.470 | 1350 |
| 1360 | 15.470 | 15.484 | 15.498 | 15.512 | 15.526 | 15.540 | 15.555 | 15.569 | 15.583 | 15.597 | 15.611 | 1360 |
| 1370 | 15.611 | 15.625 | 15.639 | 15.653 | 15.667 | 15.682 | 15.696 | 15.710 | 15.724 | 15.738 | 15.752 | 1370 |
| 1380 | 15.752 | 15.766 | 15.780 | 15.795 | 15.809 | 15.823 | 15.837 | 15.851 | 15.865 | 15.879 | 15.893 | 1380 |
| 1390 | 15.893 | 15.908 | 15.922 | 15.936 | 15.950 | 15.964 | 15.978 | 15.992 | 16.006 | 16.021 | 16.035 | 1390 |
| 1400 | 16.035 | 16.049 | 16.063 | 16.077 | 16.091 | 16.105 | 16.119 | 16.134 | 16.148 | 16.162 | 16.176 | 1400 |
| 1410 | 16.176 | 16.190 | 16.204 | 16.218 | 16.232 | 16.247 | 16.261 | 16.275 | 16.289 | 16.303 | 16.317 | 1410 |
| 1420 | 16.317 | 16.331 | 16.345 | 16.360 | 16.374 | 16.388 | 16.402 | 16.416 | 16.430 | 16.444 | 16.458 | 1420 |
| 1430 | 16.458 | 16.472 | 16.487 | 16.501 | 16.515 | 16.529 | 16.543 | 16.557 | 16.571 | 16.585 | 16.599 | 1430 |
| 1440 | 16.599 | 16.614 | 16.628 | 16.642 | 16.656 | 16.670 | 16.684 | 16.698 | 16.712 | 16.726 | 16.741 | 1440 |
| 1450 | 16.741 | 16.755 | 16.769 | 16.783 | 16.797 | 16.811 | 16.825 | 16.839 | 16.853 | 16.867 | 16.882 | 1450 |
| 1460 | 16.882 | 16.896 | 16.910 | 16.924 | 16.938 | 16.952 | 16.966 | 16.980 | 16.994 | 17.008 | 17.022 | 1460 |
| 1470 | 17.022 | 17.037 | 17.051 | 17.065 | 17.079 | 17.093 | 17.107 | 17.121 | 17.135 | 17.149 | 17.163 | 1470 |
| 1480 | 17.163 | 17.177 | 17.192 | 17.206 | 17.220 | 17.234 | 17.248 | 17.262 | 17.276 | 17.290 | 17.304 | 1480 |
| 1490 | 17.304 | 17.318 | 17.332 | 17.346 | 17.360 | 17.374 | 17.388 | 17.403 | 17.417 | 17.431 | 17.445 | 1490 |
| 1500 | 17.445 | 17.459 | 17.473 | 17.487 | 17.501 | 17.515 | 17.529 | 17.543 | 17.557 | 17.571 | 17.585 | 1500 |
| 1510 | 17.585 | 17.599 | 17.613 | 17.627 | 17.641 | 17.655 | 17.669 | 17.684 | 17.698 | 17.712 | 17.726 | 1510 |
| 1520 | 17.726 | 17.740 | 17.754 | 17.768 | 17.782 | 17.796 | 17.810 | 17.824 | 17.838 | 17.852 | 17.866 | 1520 |
| 1530 | 17.866 | 17.880 | 17.894 | 17.908 | 17.922 | 17.936 | 17.950 | 17.964 | 17.978 | 17.992 | 18.006 | 1530 |
| 1540 | 18.006 | 18.020 | 18.034 | 18.048 | 18.062 | 18.076 | 18.090 | 18.104 | 18.118 | 18.132 | 18.146 | 1540 |
| 1550 | 18.146 | 18.160 | 18.174 | 18.188 | 18.202 | 18.216 | 18.230 | 18.244 | 18.258 | 18.272 | 18.286 | 1550 |
| 1560 | 18.286 | 18.299 | 18.313 | 18.327 | 18.341 | 18.355 | 18.369 | 18.383 | 18.397 | 18.411 | 18.425 | 1560 |
| 1570 | 18.425 | 18.439 | 18.453 | 18.467 | 18.481 | 18.495 | 18.509 | 18.523 | 18.537 | 18.550 | 18.564 | 1570 |
| 1580 | 18.564 | 18.578 | 18.592 | 18.606 | 18.620 | 18.634 | 18.648 | 18.662 | 18.676 | 18.690 | 18.703 | 1580 |
| 1590 | 18.703 | 18.717 | 18.731 | 18.745 | 18.759 | 18.773 | 18.787 | 18.801 | 18.815 | 18.828 | 18.842 | 1590 |
| 1600 | 18.842 | 18.856 | 18.870 | 18.884 | 18.898 | 18.912 | 18.926 | 18.939 | 18.953 | 18.967 | 18.981 | 1600 |
| 1610 | 18.981 | 18.995 | 19.009 | 19.023 | 19.036 | 19.050 | 19.064 | 19.078 | 19.092 | 19.106 | 19.119 | 1610 |
| 1620 | 19.119 | 19.133 | 19.147 | 19.161 | 19.175 | 19.188 | 19.202 | 19.216 | 19.230 | 19.244 | 19.257 | 1620 |
| 1630 | 19.257 | 19.271 | 19.285 | 19.299 | 19.313 | 19.326 | 19.340 | 19.354 | 19.368 | 19.382 | 19.395 | 1630 |
| 1640 | 19.395 | 19.409 | 19.423 | 19.437 | 19.450 | 19.464 | 19.478 | 19.492 | 19.505 | 19.519 | 19.533 | 1640 |
| 1650 | 19.533 | 19.547 | 19.560 | 19.574 | 19.588 | 19.602 | 19.615 | 19.629 | 19.643 | 19.656 | 19.670 | 1650 |
| 1660 | 19.670 | 19.684 | 19.698 | 19.711 | 19.725 | 19.739 | 19.752 | 19.766 | 19.780 | 19.793 | 19.807 | 1660 |
| 1670 | 19.807 | 19.821 | 19.834 | 19.848 | 19.862 | 19.875 | 19.889 | 19.903 | 19.916 | 19.930 | 19.944 | 1670 |
| 1680 | 19.944 | 19.957 | 19.971 | 19.985 | 19.998 | 20.012 | 20.025 | 20.039 | 20.053 | 20.066 | 20.080 | 1680 |
| 1690 | 20.080 | 20.093 | 20.107 | 20.120 | 20.134 | 20.148 | 20.161 | 20.175 | 20.188 | 20.202 | 20.215 | 1690 |
| 1700 | 20.215 | 20.229 | 20.242 | 20.256 | 20.269 | 20.283 | 20.296 | 20.309 | 20.323 | 20.336 | 20.350 | 1700 |
| 1710 | 20.350 | 20.363 | 20.377 | 20.390 | 20.403 | 20.417 | 20.430 | 20.443 | 20.457 | 20.470 | 20.483 | 1710 |
| 1720 | 20.483 | 20.497 | 20.510 | 20.523 | 20.537 | 20.550 | 20.563 | 20.576 | 20.590 | 20.603 | 20.616 | 1720 |
| 1730 | 20.616 | 20.629 | 20.642 | 20.656 | 20.669 | 20.682 | 20.695 | 20.708 | 20.721 | 20.734 | 20.748 | 1730 |
| 1740 | 20.748 | 20.761 | 20.774 | 20.787 | 20.800 | 20.813 | 20.826 | 20.839 | 20.852 | 20.865 | 20.878 | 1740 |
| 1750 | 20.878 | 20.891 | 20.904 | 20.916 | 20.929 | 20.942 | 20.955 | 20.968 | 20.981 | 20.994 | 21.006 | 1750 |
| 1760 | 21.006 | 21.019 | 21.032 | 21.045 | 21.057 | 21.070 | 21.083 | 21.096 | 21.108 | | | 1760 |
| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |

TABLE 16

TEMPERATURE-EMF FOR TYPE S THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| -50 | -0.236 | | | | | | | | | | | -50 |
| -40 | -0.194 | -0.199 | -0.203 | -0.207 | -0.211 | -0.215 | -0.220 | -0.224 | -0.228 | -0.232 | -0.236 | -40 |
| -30 | -0.150 | -0.155 | -0.159 | -0.164 | -0.168 | -0.173 | -0.177 | -0.181 | -0.186 | -0.190 | -0.194 | -30 |
| -20 | -0.103 | -0.108 | -0.112 | -0.117 | -0.122 | -0.127 | -0.132 | -0.136 | -0.141 | -0.145 | -0.150 | -20 |
| -10 | -0.053 | -0.058 | -0.063 | -0.068 | -0.073 | -0.078 | -0.083 | -0.088 | -0.093 | -0.098 | -0.103 | -10 |
| 0 | 0.000 | -0.005 | -0.011 | -0.016 | -0.021 | -0.027 | -0.032 | -0.037 | -0.042 | -0.048 | -0.053 | 0 |
| 10 | 0.055 | 0.061 | 0.067 | 0.072 | 0.078 | 0.084 | 0.090 | 0.095 | 0.101 | 0.107 | 0.113 | 10 |
| 20 | 0.113 | 0.119 | 0.125 | 0.131 | 0.137 | 0.142 | 0.148 | 0.154 | 0.161 | 0.167 | 0.173 | 20 |
| 30 | 0.173 | 0.179 | 0.185 | 0.191 | 0.197 | 0.203 | 0.210 | 0.216 | 0.222 | 0.228 | 0.235 | 30 |
| 40 | 0.235 | 0.241 | 0.247 | 0.254 | 0.260 | 0.266 | 0.273 | 0.279 | 0.286 | 0.292 | 0.299 | 40 |
| 50 | 0.299 | 0.305 | 0.312 | 0.318 | 0.325 | 0.331 | 0.338 | 0.345 | 0.351 | 0.358 | 0.365 | 50 |
| 60 | 0.365 | 0.371 | 0.378 | 0.395 | 0.391 | 0.398 | 0.405 | 0.412 | 0.419 | 0.425 | 0.432 | 60 |
| 70 | 0.432 | 0.439 | 0.446 | 0.453 | 0.460 | 0.467 | 0.474 | 0.481 | 0.488 | 0.495 | 0.502 | 70 |
| 80 | 0.502 | 0.509 | 0.516 | 0.523 | 0.530 | 0.537 | 0.544 | 0.551 | 0.558 | 0.566 | 0.573 | 80 |
| 90 | 0.573 | 0.580 | 0.587 | 0.594 | 0.602 | 0.609 | 0.616 | 0.623 | 0.631 | 0.638 | 0.645 | 90 |
| 100 | 0.645 | 0.653 | 0.660 | 0.667 | 0.675 | 0.682 | 0.690 | 0.697 | 0.704 | 0.712 | 0.719 | 100 |
| 110 | 0.719 | 0.727 | 0.734 | 0.742 | 0.749 | 0.757 | 0.764 | 0.772 | 0.780 | 0.787 | 0.795 | 110 |
| 120 | 0.795 | 0.802 | 0.810 | 0.818 | 0.825 | 0.833 | 0.841 | 0.848 | 0.856 | 0.864 | 0.872 | 120 |
| 130 | 0.872 | 0.879 | 0.887 | 0.895 | 0.903 | 0.910 | 0.918 | 0.926 | 0.934 | 0.942 | 0.950 | 130 |
| 140 | 0.950 | 0.957 | 0.965 | 0.973 | 0.981 | 0.989 | 0.997 | 1.005 | 1.013 | 1.021 | 1.029 | 140 |
| 150 | 1.029 | 1.037 | 1.045 | 1.053 | 1.061 | 1.069 | 1.077 | 1.085 | 1.093 | 1.101 | 1.109 | 150 |
| 160 | 1.109 | 1.117 | 1.125 | 1.133 | 1.141 | 1.149 | 1.158 | 1.166 | 1.174 | 1.182 | 1.190 | 160 |
| 170 | 1.190 | 1.198 | 1.207 | 1.215 | 1.223 | 1.231 | 1.240 | 1.248 | 1.256 | 1.264 | 1.273 | 170 |
| 180 | 1.273 | 1.281 | 1.289 | 1.297 | 1.306 | 1.314 | 1.322 | 1.331 | 1.339 | 1.347 | 1.356 | 180 |
| 190 | 1.356 | 1.364 | 1.373 | 1.381 | 1.389 | 1.398 | 1.406 | 1.415 | 1.423 | 1.432 | 1.440 | 190 |
| 200 | 1.440 | 1.448 | 1.457 | 1.465 | 1.474 | 1.482 | 1.491 | 1.499 | 1.508 | 1.516 | 1.525 | 200 |
| 210 | 1.525 | 1.534 | 1.542 | 1.551 | 1.559 | 1.568 | 1.576 | 1.585 | 1.594 | 1.602 | 1.611 | 210 |
| 220 | 1.611 | 1.620 | 1.628 | 1.637 | 1.645 | 1.654 | 1.663 | 1.671 | 1.680 | 1.689 | 1.698 | 220 |
| 230 | 1.698 | 1.706 | 1.715 | 1.724 | 1.732 | 1.741 | 1.750 | 1.759 | 1.767 | 1.776 | 1.785 | 230 |
| 240 | 1.785 | 1.794 | 1.802 | 1.811 | 1.820 | 1.829 | 1.838 | 1.846 | 1.855 | 1.864 | 1.873 | 240 |
| 250 | 1.873 | 1.882 | 1.891 | 1.899 | 1.908 | 1.917 | 1.926 | 1.935 | 1.944 | 1.953 | 1.962 | 250 |
| 260 | 1.962 | 1.971 | 1.979 | 1.988 | 1.997 | 2.006 | 2.015 | 2.024 | 2.033 | 2.042 | 2.051 | 260 |
| 270 | 2.051 | 2.060 | 2.069 | 2.078 | 2.087 | 2.096 | 2.105 | 2.114 | 2.123 | 2.132 | 2.141 | 270 |
| 280 | 2.141 | 2.150 | 2.159 | 2.168 | 2.177 | 2.186 | 2.195 | 2.204 | 2.213 | 2.222 | 2.232 | 280 |
| 290 | 2.232 | 2.241 | 2.250 | 2.259 | 2.268 | 2.277 | 2.286 | 2.295 | 2.304 | 2.314 | 2.323 | 290 |
| 300 | 2.323 | 2.332 | 2.341 | 2.350 | 2.359 | 2.368 | 2.378 | 2.387 | 2.396 | 2.405 | 2.414 | 300 |
| 310 | 2.414 | 2.424 | 2.433 | 2.442 | 2.451 | 2.460 | 2.470 | 2.479 | 2.488 | 2.497 | 2.506 | 310 |
| 320 | 2.506 | 2.516 | 2.525 | 2.534 | 2.543 | 2.553 | 2.562 | 2.571 | 2.581 | 2.590 | 2.599 | 320 |
| 330 | 2.599 | 2.608 | 2.618 | 2.627 | 2.636 | 2.646 | 2.655 | 2.664 | 2.674 | 2.683 | 2.692 | 330 |
| 340 | 2.692 | 2.702 | 2.711 | 2.720 | 2.730 | 2.739 | 2.748 | 2.758 | 2.767 | 2.776 | 2.786 | 340 |
| 350 | 2.786 | 2.795 | 2.805 | 2.814 | 2.823 | 2.833 | 2.842 | 2.852 | 2.861 | 2.870 | 2.880 | 350 |
| 360 | 2.880 | 2.889 | 2.899 | 2.908 | 2.917 | 2.927 | 2.936 | 2.946 | 2.955 | 2.965 | 2.974 | 360 |
| 370 | 2.974 | 2.984 | 2.993 | 3.003 | 3.012 | 3.022 | 3.031 | 3.041 | 3.050 | 3.059 | 3.069 | 370 |
| 380 | 3.069 | 3.078 | 3.088 | 3.097 | 3.107 | 3.117 | 3.126 | 3.136 | 3.145 | 3.155 | 3.164 | 380 |
| 390 | 3.164 | 3.174 | 3.183 | 3.193 | 3.202 | 3.212 | 3.221 | 3.231 | 3.241 | 3.250 | 3.260 | 390 |
| 400 | 3.260 | 3.269 | 3.279 | 3.288 | 3.298 | 3.308 | 3.317 | 3.327 | 3.336 | 3.346 | 3.356 | 400 |
| 410 | 3.356 | 3.365 | 3.375 | 3.384 | 3.394 | 3.404 | 3.413 | 3.423 | 3.433 | 3.442 | 3.452 | 410 |
| 420 | 3.452 | 3.462 | 3.471 | 3.481 | 3.491 | 3.500 | 3.510 | 3.520 | 3.529 | 3.539 | 3.549 | 420 |
| 430 | 3.549 | 3.558 | 3.568 | 3.578 | 3.587 | 3.597 | 3.607 | 3.616 | 3.626 | 3.636 | 3.645 | 430 |
| 440 | 3.645 | 3.655 | 3.665 | 3.675 | 3.684 | 3.694 | 3.704 | 3.714 | 3.723 | 3.733 | 3.743 | 440 |
| 450 | 3.743 | 3.752 | 3.762 | 3.772 | 3.782 | 3.791 | 3.801 | 3.811 | 3.821 | 3.831 | 3.840 | 450 |
| 460 | 3.840 | 3.850 | 3.860 | 3.870 | 3.879 | 3.889 | 3.899 | 3.909 | 3.919 | 3.928 | 3.938 | 460 |
| 470 | 3.938 | 3.948 | 3.958 | 3.968 | 3.977 | 3.987 | 3.997 | 4.007 | 4.017 | 4.027 | 4.036 | 470 |
| 480 | 4.036 | 4.046 | 4.056 | 4.066 | 4.076 | 4.086 | 4.095 | 4.105 | 4.115 | 4.125 | 4.135 | 480 |
| 490 | 4.135 | 4.145 | 4.155 | 4.164 | 4.174 | 4.184 | 4.194 | 4.204 | 4.214 | 4.224 | 4.234 | 490 |
| 500 | 4.234 | 4.243 | 4.253 | 4.263 | 4.273 | 4.283 | 4.293 | 4.303 | 4.313 | 4.323 | 4.333 | 500 |
| 510 | 4.333 | 4.343 | 4.352 | 4.362 | 4.372 | 4.382 | 4.392 | 4.402 | 4.412 | 4.422 | 4.432 | 510 |
| 520 | 4.432 | 4.442 | 4.452 | 4.462 | 4.472 | 4.482 | 4.492 | 4.502 | 4.512 | 4.522 | 4.532 | 520 |
| 530 | 4.532 | 4.542 | 4.552 | 4.562 | 4.572 | 4.582 | 4.592 | 4.602 | 4.612 | 4.622 | 4.632 | 530 |
| 540 | 4.632 | 4.642 | 4.652 | 4.662 | 4.672 | 4.682 | 4.692 | 4.702 | 4.712 | 4.722 | 4.732 | 540 |
| 550 | 4.732 | 4.742 | 4.752 | 4.762 | 4.772 | 4.782 | 4.792 | 4.802 | 4.812 | 4.822 | 4.832 | 550 |
| 560 | 4.832 | 4.842 | 4.852 | 4.862 | 4.873 | 4.883 | 4.893 | 4.903 | 4.913 | 4.923 | 4.933 | 560 |
| 570 | 4.933 | 4.943 | 4.953 | 4.963 | 4.973 | 4.984 | 4.994 | 5.004 | 5.014 | 5.024 | 5.034 | 570 |
| 580 | 5.034 | 5.044 | 5.054 | 5.065 | 5.075 | 5.085 | 5.095 | 5.105 | 5.115 | 5.125 | 5.136 | 580 |
| 590 | 5.136 | 5.146 | 5.156 | 5.166 | 5.176 | 5.186 | 5.197 | 5.207 | 5.217 | 5.227 | 5.237 | 590 |

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|-------|---|---|---|---|---|---|---|---|---|---|----|-------|
|-------|---|---|---|---|---|---|---|---|---|---|----|-------|

TABLE 16 (Continued)

TEMPERATURE-EMF FOR TYPE S THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 600 | 5.237 | 5.247 | 5.258 | 5.268 | 5.278 | 5.288 | 5.298 | 5.309 | 5.319 | 5.329 | 5.339 | 600 |
| 610 | 5.339 | 5.350 | 5.360 | 5.370 | 5.380 | 5.391 | 5.401 | 5.411 | 5.421 | 5.431 | 5.442 | 610 |
| 620 | 5.442 | 5.452 | 5.462 | 5.473 | 5.483 | 5.493 | 5.503 | 5.514 | 5.524 | 5.534 | 5.544 | 620 |
| 630 | 5.544 | 5.555 | 5.565 | 5.575 | 5.586 | 5.596 | 5.606 | 5.617 | 5.627 | 5.637 | 5.648 | 630 |
| 640 | 5.648 | 5.658 | 5.668 | 5.679 | 5.689 | 5.700 | 5.710 | 5.720 | 5.731 | 5.741 | 5.751 | 640 |
| 650 | 5.751 | 5.762 | 5.772 | 5.782 | 5.793 | 5.803 | 5.814 | 5.824 | 5.834 | 5.845 | 5.855 | 650 |
| 660 | 5.855 | 5.866 | 5.876 | 5.887 | 5.897 | 5.907 | 5.918 | 5.928 | 5.939 | 5.949 | 5.960 | 660 |
| 670 | 5.960 | 5.970 | 5.980 | 5.991 | 6.001 | 6.012 | 6.022 | 6.033 | 6.043 | 6.054 | 6.064 | 670 |
| 680 | 6.064 | 6.075 | 6.085 | 6.096 | 6.106 | 6.117 | 6.127 | 6.138 | 6.148 | 6.159 | 6.169 | 680 |
| 690 | 6.169 | 6.180 | 6.190 | 6.201 | 6.211 | 6.222 | 6.232 | 6.243 | 6.253 | 6.264 | 6.274 | 690 |
| 700 | 6.274 | 6.285 | 6.295 | 6.306 | 6.316 | 6.327 | 6.338 | 6.348 | 6.359 | 6.369 | 6.380 | 700 |
| 710 | 6.380 | 6.390 | 6.401 | 6.412 | 6.422 | 6.433 | 6.443 | 6.454 | 6.465 | 6.475 | 6.486 | 710 |
| 720 | 6.486 | 6.496 | 6.507 | 6.518 | 6.528 | 6.539 | 6.549 | 6.560 | 6.571 | 6.581 | 6.592 | 720 |
| 730 | 6.592 | 6.603 | 6.613 | 6.624 | 6.635 | 6.645 | 6.656 | 6.667 | 6.677 | 6.688 | 6.699 | 730 |
| 740 | 6.699 | 6.709 | 6.720 | 6.731 | 6.741 | 6.752 | 6.763 | 6.773 | 6.784 | 6.795 | 6.805 | 740 |
| 750 | 6.805 | 6.816 | 6.827 | 6.838 | 6.848 | 6.859 | 6.870 | 6.880 | 6.891 | 6.902 | 6.913 | 750 |
| 760 | 6.913 | 6.923 | 6.934 | 6.945 | 6.956 | 6.966 | 6.977 | 6.988 | 6.995 | 7.009 | 7.020 | 760 |
| 770 | 7.020 | 7.031 | 7.042 | 7.053 | 7.063 | 7.074 | 7.085 | 7.096 | 7.107 | 7.117 | 7.128 | 770 |
| 780 | 7.128 | 7.139 | 7.150 | 7.161 | 7.171 | 7.182 | 7.193 | 7.204 | 7.215 | 7.225 | 7.236 | 780 |
| 790 | 7.236 | 7.247 | 7.258 | 7.269 | 7.280 | 7.291 | 7.301 | 7.312 | 7.323 | 7.334 | 7.345 | 790 |
| 800 | 7.345 | 7.356 | 7.367 | 7.377 | 7.388 | 7.399 | 7.410 | 7.421 | 7.432 | 7.443 | 7.454 | 800 |
| 810 | 7.454 | 7.465 | 7.476 | 7.486 | 7.497 | 7.508 | 7.519 | 7.530 | 7.541 | 7.552 | 7.563 | 810 |
| 820 | 7.563 | 7.574 | 7.585 | 7.596 | 7.607 | 7.618 | 7.629 | 7.640 | 7.651 | 7.661 | 7.672 | 820 |
| 830 | 7.672 | 7.683 | 7.694 | 7.705 | 7.716 | 7.727 | 7.738 | 7.749 | 7.760 | 7.771 | 7.782 | 830 |
| 840 | 7.782 | 7.793 | 7.804 | 7.815 | 7.826 | 7.837 | 7.848 | 7.859 | 7.870 | 7.881 | 7.892 | 840 |
| 850 | 7.892 | 7.904 | 7.915 | 7.926 | 7.937 | 7.948 | 7.959 | 7.970 | 7.981 | 7.992 | 8.003 | 850 |
| 860 | 8.003 | 8.014 | 8.025 | 8.036 | 8.047 | 8.058 | 8.069 | 8.081 | 8.092 | 8.103 | 8.114 | 860 |
| 870 | 8.114 | 8.125 | 8.136 | 8.147 | 8.158 | 8.169 | 8.180 | 8.192 | 8.203 | 8.214 | 8.225 | 870 |
| 880 | 8.225 | 8.236 | 8.247 | 8.258 | 8.270 | 8.281 | 8.292 | 8.303 | 8.314 | 8.325 | 8.336 | 880 |
| 890 | 8.336 | 8.348 | 8.359 | 8.370 | 8.381 | 8.392 | 8.404 | 8.415 | 8.426 | 8.437 | 8.448 | 890 |
| 900 | 8.448 | 8.460 | 8.471 | 8.482 | 8.493 | 8.504 | 8.516 | 8.527 | 8.538 | 8.549 | 8.560 | 900 |
| 910 | 8.560 | 8.572 | 8.583 | 8.594 | 8.605 | 8.617 | 8.628 | 8.639 | 8.650 | 8.662 | 8.673 | 910 |
| 920 | 8.673 | 8.684 | 8.695 | 8.707 | 8.718 | 8.729 | 8.741 | 8.752 | 8.763 | 8.774 | 8.786 | 920 |
| 930 | 8.786 | 8.797 | 8.808 | 8.820 | 8.831 | 8.842 | 8.854 | 8.865 | 8.876 | 8.888 | 8.899 | 930 |
| 940 | 8.899 | 8.910 | 8.922 | 8.933 | 8.944 | 8.956 | 8.967 | 8.978 | 8.990 | 9.001 | 9.012 | 940 |
| 950 | 9.012 | 9.024 | 9.035 | 9.047 | 9.058 | 9.069 | 9.081 | 9.092 | 9.103 | 9.115 | 9.126 | 950 |
| 960 | 9.126 | 9.138 | 9.149 | 9.160 | 9.172 | 9.183 | 9.195 | 9.206 | 9.217 | 9.229 | 9.240 | 960 |
| 970 | 9.240 | 9.252 | 9.263 | 9.275 | 9.286 | 9.298 | 9.309 | 9.320 | 9.332 | 9.343 | 9.355 | 970 |
| 980 | 9.355 | 9.366 | 9.378 | 9.389 | 9.401 | 9.412 | 9.424 | 9.435 | 9.447 | 9.458 | 9.470 | 980 |
| 990 | 9.470 | 9.481 | 9.493 | 9.504 | 9.516 | 9.527 | 9.539 | 9.550 | 9.562 | 9.573 | 9.585 | 990 |
| 1000 | 9.585 | 9.596 | 9.608 | 9.619 | 9.631 | 9.642 | 9.654 | 9.665 | 9.677 | 9.689 | 9.700 | 1000 |
| 1010 | 9.700 | 9.712 | 9.723 | 9.735 | 9.746 | 9.758 | 9.770 | 9.781 | 9.793 | 9.804 | 9.816 | 1010 |
| 1020 | 9.816 | 9.828 | 9.839 | 9.851 | 9.862 | 9.874 | 9.886 | 9.897 | 9.909 | 9.920 | 9.932 | 1020 |
| 1030 | 9.932 | 9.944 | 9.955 | 9.967 | 9.979 | 9.990 | 10.002 | 10.013 | 10.025 | 10.037 | 10.048 | 1030 |
| 1040 | 10.048 | 10.060 | 10.072 | 10.083 | 10.095 | 10.107 | 10.118 | 10.130 | 10.142 | 10.154 | 10.165 | 1040 |
| 1050 | 10.165 | 10.177 | 10.189 | 10.200 | 10.212 | 10.224 | 10.235 | 10.247 | 10.259 | 10.271 | 10.282 | 1050 |
| 1060 | 10.282 | 10.294 | 10.306 | 10.318 | 10.329 | 10.341 | 10.353 | 10.364 | 10.376 | 10.388 | 10.400 | 1060 |
| 1070 | 10.400 | 10.411 | 10.423 | 10.435 | 10.447 | 10.459 | 10.470 | 10.482 | 10.494 | 10.506 | 10.517 | 1070 |
| 1080 | 10.517 | 10.529 | 10.541 | 10.553 | 10.565 | 10.576 | 10.588 | 10.600 | 10.612 | 10.624 | 10.635 | 1080 |
| 1090 | 10.635 | 10.647 | 10.659 | 10.671 | 10.683 | 10.694 | 10.706 | 10.718 | 10.730 | 10.742 | 10.754 | 1090 |
| 1100 | 10.754 | 10.765 | 10.777 | 10.789 | 10.801 | 10.813 | 10.825 | 10.836 | 10.848 | 10.860 | 10.872 | 1100 |
| 1110 | 10.872 | 10.884 | 10.896 | 10.908 | 10.919 | 10.931 | 10.943 | 10.955 | 10.967 | 10.979 | 10.991 | 1110 |
| 1120 | 10.991 | 11.003 | 11.014 | 11.026 | 11.038 | 11.050 | 11.062 | 11.074 | 11.086 | 11.098 | 11.110 | 1120 |
| 1130 | 11.110 | 11.121 | 11.133 | 11.145 | 11.157 | 11.169 | 11.181 | 11.193 | 11.205 | 11.217 | 11.229 | 1130 |
| 1140 | 11.229 | 11.241 | 11.252 | 11.264 | 11.276 | 11.288 | 11.300 | 11.312 | 11.324 | 11.336 | 11.348 | 1140 |
| 1150 | 11.348 | 11.360 | 11.372 | 11.384 | 11.396 | 11.408 | 11.420 | 11.432 | 11.443 | 11.455 | 11.467 | 1150 |
| 1160 | 11.467 | 11.479 | 11.491 | 11.503 | 11.515 | 11.527 | 11.539 | 11.551 | 11.563 | 11.575 | 11.587 | 1160 |
| 1170 | 11.587 | 11.599 | 11.611 | 11.623 | 11.635 | 11.647 | 11.659 | 11.671 | 11.683 | 11.695 | 11.707 | 1170 |
| 1180 | 11.707 | 11.719 | 11.731 | 11.743 | 11.755 | 11.767 | 11.779 | 11.791 | 11.803 | 11.815 | 11.827 | 1180 |
| 1190 | 11.827 | 11.839 | 11.851 | 11.863 | 11.875 | 11.887 | 11.899 | 11.911 | 11.923 | 11.935 | 11.947 | 1190 |
| 1200 | 11.947 | 11.959 | 11.971 | 11.983 | 11.995 | 12.007 | 12.019 | 12.031 | 12.043 | 12.055 | 12.067 | 1200 |
| 1210 | 12.067 | 12.079 | 12.091 | 12.103 | 12.116 | 12.128 | 12.140 | 12.152 | 12.164 | 12.176 | 12.188 | 1210 |
| 1220 | 12.188 | 12.200 | 12.212 | 12.224 | 12.236 | 12.248 | 12.260 | 12.272 | 12.284 | 12.296 | 12.308 | 1220 |
| 1230 | 12.308 | 12.320 | 12.332 | 12.345 | 12.357 | 12.369 | 12.381 | 12.393 | 12.405 | 12.417 | 12.429 | 1230 |
| 1240 | 12.429 | 12.441 | 12.453 | 12.465 | 12.477 | 12.489 | 12.501 | 12.514 | 12.526 | 12.538 | 12.550 | 1240 |

DEG C 0 1 2 3 4 5 6 7 8 9 10 DEG C

TABLE 16 (Continued)

TEMPERATURE-EMF FOR TYPE S THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68)

REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 1250 | 12.550 | 12.562 | 12.574 | 12.586 | 12.598 | 12.610 | 12.622 | 12.634 | 12.647 | 12.659 | 12.671 | 1250 |
| 1260 | 12.671 | 12.683 | 12.695 | 12.707 | 12.719 | 12.731 | 12.743 | 12.755 | 12.767 | 12.780 | 12.792 | 1260 |
| 1270 | 12.792 | 12.804 | 12.816 | 12.828 | 12.840 | 12.852 | 12.864 | 12.876 | 12.888 | 12.901 | 12.913 | 1270 |
| 1280 | 12.913 | 12.925 | 12.937 | 12.949 | 12.961 | 12.973 | 12.985 | 12.997 | 13.010 | 13.022 | 13.034 | 1280 |
| 1290 | 13.034 | 13.046 | 13.058 | 13.070 | 13.082 | 13.094 | 13.107 | 13.119 | 13.131 | 13.143 | 13.155 | 1290 |
| 1300 | 13.155 | 13.167 | 13.179 | 13.191 | 13.203 | 13.216 | 13.228 | 13.240 | 13.252 | 13.264 | 13.276 | 1300 |
| 1310 | 13.276 | 13.288 | 13.300 | 13.313 | 13.325 | 13.337 | 13.349 | 13.361 | 13.373 | 13.385 | 13.397 | 1310 |
| 1320 | 13.397 | 13.410 | 13.422 | 13.434 | 13.446 | 13.458 | 13.470 | 13.482 | 13.495 | 13.507 | 13.519 | 1320 |
| 1330 | 13.519 | 13.531 | 13.543 | 13.555 | 13.567 | 13.579 | 13.592 | 13.604 | 13.616 | 13.628 | 13.640 | 1330 |
| 1340 | 13.640 | 13.652 | 13.664 | 13.677 | 13.689 | 13.701 | 13.713 | 13.725 | 13.737 | 13.749 | 13.761 | 1340 |
| 1350 | 13.761 | 13.774 | 13.786 | 13.798 | 13.810 | 13.822 | 13.834 | 13.846 | 13.859 | 13.871 | 13.883 | 1350 |
| 1360 | 13.883 | 13.895 | 13.907 | 13.919 | 13.931 | 13.943 | 13.956 | 13.968 | 13.980 | 13.992 | 14.004 | 1360 |
| 1370 | 14.004 | 14.016 | 14.028 | 14.040 | 14.053 | 14.065 | 14.077 | 14.089 | 14.101 | 14.113 | 14.125 | 1370 |
| 1380 | 14.125 | 14.138 | 14.150 | 14.162 | 14.174 | 14.186 | 14.198 | 14.210 | 14.222 | 14.235 | 14.247 | 1380 |
| 1390 | 14.247 | 14.259 | 14.271 | 14.283 | 14.295 | 14.307 | 14.319 | 14.332 | 14.344 | 14.356 | 14.368 | 1390 |
| 1400 | 14.368 | 14.380 | 14.392 | 14.404 | 14.416 | 14.429 | 14.441 | 14.453 | 14.465 | 14.477 | 14.489 | 1400 |
| 1410 | 14.489 | 14.501 | 14.513 | 14.526 | 14.538 | 14.550 | 14.562 | 14.574 | 14.586 | 14.598 | 14.610 | 1410 |
| 1420 | 14.610 | 14.622 | 14.635 | 14.647 | 14.659 | 14.671 | 14.683 | 14.695 | 14.707 | 14.719 | 14.731 | 1420 |
| 1430 | 14.731 | 14.744 | 14.756 | 14.768 | 14.780 | 14.792 | 14.804 | 14.816 | 14.828 | 14.840 | 14.852 | 1430 |
| 1440 | 14.852 | 14.865 | 14.877 | 14.889 | 14.901 | 14.913 | 14.925 | 14.937 | 14.949 | 14.961 | 14.973 | 1440 |
| 1450 | 14.973 | 14.985 | 14.998 | 15.010 | 15.022 | 15.034 | 15.046 | 15.058 | 15.070 | 15.082 | 15.094 | 1450 |
| 1460 | 15.094 | 15.106 | 15.118 | 15.130 | 15.143 | 15.155 | 15.167 | 15.179 | 15.191 | 15.203 | 15.215 | 1460 |
| 1470 | 15.215 | 15.227 | 15.239 | 15.251 | 15.263 | 15.275 | 15.287 | 15.299 | 15.311 | 15.324 | 15.336 | 1470 |
| 1480 | 15.336 | 15.348 | 15.360 | 15.372 | 15.384 | 15.396 | 15.408 | 15.420 | 15.432 | 15.444 | 15.456 | 1480 |
| 1490 | 15.456 | 15.468 | 15.480 | 15.492 | 15.504 | 15.516 | 15.528 | 15.540 | 15.552 | 15.564 | 15.576 | 1490 |
| 1500 | 15.576 | 15.589 | 15.601 | 15.613 | 15.625 | 15.637 | 15.649 | 15.661 | 15.673 | 15.685 | 15.697 | 1500 |
| 1510 | 15.697 | 15.709 | 15.721 | 15.733 | 15.745 | 15.757 | 15.769 | 15.781 | 15.793 | 15.805 | 15.817 | 1510 |
| 1520 | 15.817 | 15.829 | 15.841 | 15.853 | 15.865 | 15.877 | 15.889 | 15.901 | 15.913 | 15.925 | 15.937 | 1520 |
| 1530 | 15.937 | 15.949 | 15.961 | 15.973 | 15.985 | 15.997 | 16.009 | 16.021 | 16.033 | 16.045 | 16.057 | 1530 |
| 1540 | 16.057 | 16.069 | 16.080 | 16.092 | 16.104 | 16.116 | 16.128 | 16.140 | 16.152 | 16.164 | 16.176 | 1540 |
| 1550 | 16.176 | 16.188 | 16.200 | 16.212 | 16.224 | 16.236 | 16.248 | 16.260 | 16.272 | 16.284 | 16.296 | 1550 |
| 1560 | 16.296 | 16.308 | 16.319 | 16.331 | 16.343 | 16.355 | 16.367 | 16.379 | 16.391 | 16.403 | 16.415 | 1560 |
| 1570 | 16.415 | 16.427 | 16.439 | 16.451 | 16.462 | 16.474 | 16.486 | 16.498 | 16.510 | 16.522 | 16.534 | 1570 |
| 1580 | 16.534 | 16.546 | 16.558 | 16.569 | 16.581 | 16.593 | 16.605 | 16.617 | 16.629 | 16.641 | 16.653 | 1580 |
| 1590 | 16.653 | 16.664 | 16.676 | 16.688 | 16.700 | 16.712 | 16.724 | 16.736 | 16.747 | 16.759 | 16.771 | 1590 |
| 1600 | 16.771 | 16.783 | 16.795 | 16.807 | 16.819 | 16.830 | 16.842 | 16.854 | 16.866 | 16.878 | 16.890 | 1600 |
| 1610 | 16.890 | 16.901 | 16.913 | 16.925 | 16.937 | 16.949 | 16.960 | 16.972 | 16.984 | 16.996 | 17.008 | 1610 |
| 1620 | 17.008 | 17.019 | 17.031 | 17.043 | 17.055 | 17.067 | 17.078 | 17.090 | 17.102 | 17.114 | 17.125 | 1620 |
| 1630 | 17.125 | 17.137 | 17.149 | 17.161 | 17.173 | 17.184 | 17.196 | 17.208 | 17.220 | 17.231 | 17.243 | 1630 |
| 1640 | 17.243 | 17.255 | 17.267 | 17.278 | 17.290 | 17.302 | 17.313 | 17.325 | 17.337 | 17.349 | 17.360 | 1640 |
| 1650 | 17.360 | 17.372 | 17.384 | 17.396 | 17.407 | 17.419 | 17.431 | 17.442 | 17.454 | 17.466 | 17.477 | 1650 |
| 1660 | 17.477 | 17.489 | 17.501 | 17.512 | 17.524 | 17.536 | 17.548 | 17.559 | 17.571 | 17.583 | 17.594 | 1660 |
| 1670 | 17.594 | 17.606 | 17.617 | 17.629 | 17.641 | 17.652 | 17.664 | 17.676 | 17.687 | 17.699 | 17.711 | 1670 |
| 1680 | 17.711 | 17.722 | 17.734 | 17.745 | 17.757 | 17.769 | 17.780 | 17.792 | 17.803 | 17.815 | 17.826 | 1680 |
| 1690 | 17.826 | 17.838 | 17.850 | 17.861 | 17.873 | 17.884 | 17.896 | 17.907 | 17.919 | 17.930 | 17.942 | 1690 |
| 1700 | 17.942 | 17.953 | 17.965 | 17.976 | 17.988 | 17.999 | 18.010 | 18.022 | 18.033 | 18.045 | 18.056 | 1700 |
| 1710 | 18.056 | 18.068 | 18.079 | 18.090 | 18.102 | 18.113 | 18.124 | 18.136 | 18.147 | 18.158 | 18.170 | 1710 |
| 1720 | 18.170 | 18.181 | 18.192 | 18.204 | 18.215 | 18.226 | 18.237 | 18.249 | 18.260 | 18.271 | 18.282 | 1720 |
| 1730 | 18.282 | 18.293 | 18.305 | 18.316 | 18.327 | 18.338 | 18.349 | 18.360 | 18.372 | 18.383 | 18.394 | 1730 |
| 1740 | 18.394 | 18.405 | 18.416 | 18.427 | 18.438 | 18.449 | 18.460 | 18.471 | 18.482 | 18.493 | 18.504 | 1740 |
| 1750 | 18.504 | 18.515 | 18.526 | 18.536 | 18.547 | 18.558 | 18.569 | 18.580 | 18.591 | 18.602 | 18.612 | 1750 |
| 1760 | 18.612 | 18.623 | 18.634 | 18.645 | 18.655 | 18.666 | 18.677 | 18.687 | 18.698 | | | 1760 |

TABLE 17
TEMPERATURE-EMF FOR TYPE T THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68) REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| -270 | -6.258 | | | | | | | | | | | -270 |
| -260 | -6.232 | -6.236 | -6.239 | -6.242 | -6.245 | -6.248 | -6.251 | -6.253 | -6.255 | -6.256 | -6.258 | -260 |
| -250 | -6.181 | -6.187 | -6.193 | -6.198 | -6.204 | -6.209 | -6.214 | -6.219 | -6.224 | -6.228 | -6.232 | -250 |
| -240 | -6.105 | -6.114 | -6.122 | -6.130 | -6.138 | -6.146 | -6.153 | -6.160 | -6.167 | -6.174 | -6.181 | -240 |
| -230 | -6.007 | -6.018 | -6.028 | -6.039 | -6.049 | -6.059 | -6.068 | -6.078 | -6.087 | -6.096 | -6.105 | -230 |
| -220 | -5.889 | -5.901 | -5.914 | -5.926 | -5.938 | -5.950 | -5.962 | -5.973 | -5.985 | -5.996 | -6.007 | -220 |
| -210 | -5.753 | -5.767 | -5.782 | -5.795 | -5.809 | -5.823 | -5.836 | -5.850 | -5.863 | -5.876 | -5.889 | -210 |
| -200 | -5.603 | -5.619 | -5.634 | -5.650 | -5.665 | -5.680 | -5.695 | -5.710 | -5.724 | -5.739 | -5.753 | -200 |
| -190 | -5.439 | -5.456 | -5.473 | -5.489 | -5.506 | -5.522 | -5.539 | -5.555 | -5.571 | -5.587 | -5.603 | -190 |
| -180 | -5.261 | -5.279 | -5.297 | -5.315 | -5.333 | -5.351 | -5.369 | -5.387 | -5.404 | -5.421 | -5.439 | -180 |
| -170 | -5.069 | -5.089 | -5.109 | -5.128 | -5.147 | -5.167 | -5.186 | -5.205 | -5.223 | -5.242 | -5.261 | -170 |
| -160 | -4.865 | -4.886 | -4.907 | -4.928 | -4.948 | -4.969 | -4.989 | -5.010 | -5.030 | -5.050 | -5.069 | -160 |
| -150 | -4.648 | -4.670 | -4.693 | -4.715 | -4.737 | -4.758 | -4.780 | -4.801 | -4.823 | -4.844 | -4.865 | -150 |
| -140 | -4.419 | -4.442 | -4.466 | -4.489 | -4.512 | -4.535 | -4.558 | -4.581 | -4.603 | -4.626 | -4.648 | -140 |
| -130 | -4.177 | -4.202 | -4.226 | -4.251 | -4.275 | -4.299 | -4.323 | -4.347 | -4.371 | -4.395 | -4.419 | -130 |
| -120 | -3.923 | -3.949 | -3.974 | -4.000 | -4.026 | -4.051 | -4.077 | -4.102 | -4.127 | -4.152 | -4.177 | -120 |
| -110 | -3.656 | -3.684 | -3.711 | -3.737 | -3.764 | -3.791 | -3.818 | -3.844 | -3.870 | -3.897 | -3.923 | -110 |
| -100 | -3.378 | -3.407 | -3.435 | -3.463 | -3.491 | -3.519 | -3.547 | -3.574 | -3.602 | -3.629 | -3.656 | -100 |
| -90 | -3.086 | -3.118 | -3.147 | -3.177 | -3.206 | -3.235 | -3.264 | -3.293 | -3.321 | -3.350 | -3.378 | -90 |
| -80 | -2.788 | -2.818 | -2.849 | -2.879 | -2.909 | -2.939 | -2.970 | -2.999 | -3.029 | -3.059 | -3.089 | -80 |
| -70 | -2.475 | -2.507 | -2.535 | -2.570 | -2.602 | -2.633 | -2.664 | -2.695 | -2.726 | -2.757 | -2.788 | -70 |
| -60 | -2.152 | -2.185 | -2.218 | -2.250 | -2.283 | -2.315 | -2.348 | -2.380 | -2.412 | -2.444 | -2.475 | -60 |
| -50 | -1.819 | -1.853 | -1.886 | -1.920 | -1.953 | -1.987 | -2.020 | -2.053 | -2.087 | -2.120 | -2.152 | -50 |
| -40 | -1.475 | -1.510 | -1.544 | -1.579 | -1.614 | -1.648 | -1.682 | -1.717 | -1.751 | -1.785 | -1.819 | -40 |
| -30 | -1.121 | -1.157 | -1.192 | -1.228 | -1.263 | -1.299 | -1.334 | -1.370 | -1.405 | -1.440 | -1.475 | -30 |
| -20 | -0.757 | -0.794 | -0.830 | -0.867 | -0.903 | -0.940 | -0.976 | -1.013 | -1.049 | -1.085 | -1.121 | -20 |
| -10 | -0.383 | -0.421 | -0.458 | -0.496 | -0.534 | -0.571 | -0.608 | -0.646 | -0.683 | -0.720 | -0.757 | -10 |
| 0 | 0.000 | -0.039 | -0.077 | -0.116 | -0.154 | -0.193 | -0.231 | -0.269 | -0.307 | -0.345 | -0.383 | 0 |
| 10 | 0.391 | 0.430 | 0.470 | 0.510 | 0.549 | 0.589 | 0.629 | 0.669 | 0.709 | 0.749 | 0.789 | 10 |
| 20 | 0.789 | 0.830 | 0.870 | 0.911 | 0.951 | 0.992 | 1.032 | 1.073 | 1.114 | 1.155 | 1.196 | 20 |
| 30 | 1.196 | 1.237 | 1.279 | 1.320 | 1.361 | 1.403 | 1.444 | 1.486 | 1.528 | 1.569 | 1.611 | 30 |
| 40 | 1.611 | 1.653 | 1.695 | 1.738 | 1.780 | 1.822 | 1.865 | 1.907 | 1.950 | 1.992 | 2.035 | 40 |
| 50 | 2.035 | 2.078 | 2.121 | 2.164 | 2.207 | 2.250 | 2.294 | 2.337 | 2.380 | 2.424 | 2.467 | 50 |
| 60 | 2.467 | 2.511 | 2.555 | 2.599 | 2.643 | 2.687 | 2.731 | 2.775 | 2.819 | 2.864 | 2.908 | 60 |
| 70 | 2.908 | 2.953 | 2.997 | 3.042 | 3.087 | 3.131 | 3.176 | 3.221 | 3.266 | 3.312 | 3.357 | 70 |
| 80 | 3.357 | 3.402 | 3.447 | 3.493 | 3.538 | 3.584 | 3.630 | 3.676 | 3.721 | 3.767 | 3.813 | 80 |
| 90 | 3.813 | 3.859 | 3.906 | 3.952 | 3.998 | 4.044 | 4.091 | 4.137 | 4.184 | 4.231 | 4.277 | 90 |
| 100 | 4.277 | 4.324 | 4.371 | 4.418 | 4.465 | 4.512 | 4.559 | 4.607 | 4.654 | 4.701 | 4.749 | 100 |
| 110 | 4.749 | 4.796 | 4.844 | 4.891 | 4.939 | 4.987 | 5.035 | 5.083 | 5.131 | 5.179 | 5.227 | 110 |
| 120 | 5.227 | 5.275 | 5.324 | 5.372 | 5.420 | 5.469 | 5.517 | 5.566 | 5.615 | 5.663 | 5.712 | 120 |
| 130 | 5.712 | 5.761 | 5.810 | 5.859 | 5.908 | 5.957 | 6.007 | 6.056 | 6.105 | 6.155 | 6.204 | 130 |
| 140 | 6.204 | 6.254 | 6.303 | 6.353 | 6.403 | 6.452 | 6.502 | 6.552 | 6.602 | 6.652 | 6.702 | 140 |
| 150 | 6.702 | 6.753 | 6.803 | 6.853 | 6.903 | 6.954 | 7.004 | 7.055 | 7.106 | 7.156 | 7.207 | 150 |
| 160 | 7.207 | 7.258 | 7.309 | 7.360 | 7.411 | 7.462 | 7.513 | 7.564 | 7.615 | 7.666 | 7.718 | 160 |
| 170 | 7.718 | 7.769 | 7.821 | 7.872 | 7.924 | 7.975 | 8.027 | 8.079 | 8.131 | 8.183 | 8.235 | 170 |
| 180 | 8.235 | 8.287 | 8.339 | 8.391 | 8.443 | 8.495 | 8.548 | 8.600 | 8.652 | 8.705 | 8.757 | 180 |
| 190 | 8.757 | 8.810 | 8.863 | 8.915 | 8.968 | 9.021 | 9.074 | 9.127 | 9.180 | 9.233 | 9.286 | 190 |
| 200 | 9.286 | 9.339 | 9.392 | 9.446 | 9.499 | 9.553 | 9.606 | 9.659 | 9.713 | 9.767 | 9.820 | 200 |
| 210 | 9.820 | 9.874 | 9.928 | 9.982 | 10.036 | 10.090 | 10.144 | 10.198 | 10.252 | 10.306 | 10.360 | 210 |
| 220 | 10.360 | 10.414 | 10.469 | 10.523 | 10.578 | 10.632 | 10.687 | 10.741 | 10.796 | 10.851 | 10.905 | 220 |
| 230 | 10.905 | 10.960 | 11.015 | 11.070 | 11.125 | 11.180 | 11.235 | 11.290 | 11.345 | 11.401 | 11.456 | 230 |
| 240 | 11.456 | 11.511 | 11.566 | 11.622 | 11.677 | 11.733 | 11.788 | 11.844 | 11.900 | 11.956 | 12.011 | 240 |
| 250 | 12.011 | 12.067 | 12.123 | 12.179 | 12.235 | 12.291 | 12.347 | 12.403 | 12.459 | 12.515 | 12.572 | 250 |
| 260 | 12.572 | 12.628 | 12.684 | 12.741 | 12.797 | 12.854 | 12.910 | 12.967 | 13.024 | 13.080 | 13.137 | 260 |
| 270 | 13.137 | 13.194 | 13.251 | 13.307 | 13.364 | 13.421 | 13.478 | 13.535 | 13.592 | 13.650 | 13.707 | 270 |
| 280 | 13.707 | 13.764 | 13.821 | 13.879 | 13.936 | 13.993 | 14.051 | 14.108 | 14.166 | 14.223 | 14.281 | 280 |
| 290 | 14.281 | 14.339 | 14.396 | 14.454 | 14.512 | 14.570 | 14.628 | 14.686 | 14.744 | 14.802 | 14.860 | 290 |
| 300 | 14.860 | 14.918 | 14.976 | 15.034 | 15.092 | 15.151 | 15.209 | 15.267 | 15.326 | 15.384 | 15.443 | 300 |
| 310 | 15.443 | 15.501 | 15.560 | 15.619 | 15.677 | 15.736 | 15.795 | 15.853 | 15.912 | 15.971 | 16.030 | 310 |
| 320 | 16.030 | 16.089 | 16.148 | 16.237 | 16.266 | 16.325 | 16.384 | 16.444 | 16.503 | 16.562 | 16.621 | 320 |
| 330 | 16.621 | 16.681 | 16.740 | 16.800 | 16.859 | 16.919 | 16.978 | 17.038 | 17.097 | 17.157 | 17.217 | 330 |
| 340 | 17.217 | 17.277 | 17.336 | 17.396 | 17.456 | 17.516 | 17.576 | 17.636 | 17.696 | 17.756 | 17.816 | 340 |

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|-------|---|---|---|---|---|---|---|---|---|---|----|-------|
|-------|---|---|---|---|---|---|---|---|---|---|----|-------|

TABLE 17 (Continued)

TEMPERATURE-EMF FOR TYPE T THERMOCOUPLES

TEMPERATURES IN DEGREES CELSIUS (IPTS-68) REFERENCE JUNCTIONS AT 0°C

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|--------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| THERMOELECTRIC VOLTAGE IN MILLIVOLTS | | | | | | | | | | | | |
| 350 | 17.616 | 17.677 | 17.937 | 17.997 | 18.057 | 18.118 | 18.178 | 18.238 | 18.299 | 18.359 | 18.420 | 350 |
| 360 | 18.420 | 18.480 | 18.541 | 18.602 | 18.662 | 18.723 | 18.784 | 18.845 | 18.905 | 18.966 | 19.027 | 360 |
| 370 | 19.027 | 19.088 | 19.149 | 19.210 | 19.271 | 19.332 | 19.393 | 19.455 | 19.516 | 19.577 | 19.638 | 370 |
| 380 | 19.638 | 19.699 | 19.761 | 19.822 | 19.883 | 19.945 | 20.006 | 20.068 | 20.129 | 20.191 | 20.252 | 380 |
| 390 | 20.252 | 20.314 | 20.376 | 20.437 | 20.499 | 20.560 | 20.622 | 20.684 | 20.746 | 20.807 | 20.869 | 390 |
| 400 | 20.869 | | | | | | | | | | | 400 |

| DEG C | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | DEG C |
|-------|---|---|---|---|---|---|---|---|---|---|----|-------|
| | | | | | | | | | | | | |

APPENDICES

APPENDIX A

BARE THERMOCOUPLE ELEMENT FABRICATION

A1. General

While completely fabricated thermocouples are available commercially, this Appendix is intended to assist those who desire to fabricate their own thermocouples.

A2. Thermocouple Wires

Carefully selected and tested pairs of thermocouple wires are available commercially in standard AWG diameters. When purchased as a pair simultaneously from a single supplier, the pair will conform to the specified calibration limits and be referred to as a matched pair.

1. Interchange of a common wire between two types of thermocouples (e.g. copper-nickel from Type J to T) or even between different matched pairs of the same type may yield a thermocouple that will not conform to the specified calibration limits.
2. See Appendix D for checking procedure and a reference on calibration.

A3. Joining Thermocouple Wires

A3.1 General

The dissimilar wires of a thermocouple must be joined at the temperature measuring junction by a joint of good electrical and thermal conductivity, without destroying the mechanical and metallurgical properties of the thermocouple wires at this joint.

1. For use below 500°C (1000°F) most base metal thermocouple wires may be silver soldered using borax as a flux.
2. Above 500°C (1000°F) experience has shown that properly welded thermocouple junctions provide long life and excellent thermal and electrical properties. Welded thermocouple junctions are used in practically all industrial applications today. Noble metal thermocouples should always be joined by welding. Common methods of welding thermocouples are gas, electric arc, resistance, tungsten-inert-gas and plasma-arc welding.

A3.2 Preparation of Wires

1. Often the matched wires must be straightened prior to joining to facilitate stringing of insulators in the final thermocouple assembly, but where possible, excessive bending of thermocouple wires should be avoided because cold working may alter the EMF output of thermocouple wire. Hammering, stretching and excessive twisting should be avoided for the same reason.

2. The thermocouple wires are cut to the length desired allowing for one or two attempts at welding and for any forming that must be done at the junction.
3. All thermocouple wire should be cleaned carefully with a suitable solvent such as Freon TF*, Methyl-Ethyl-Ketone, or Alcohol (such as Isopropyl) prior to welding.
4. Simple jigs and fixtures are usually used to shape the wires prior to welding, except for butt welded thermocouples which are often bent around a mandrel after welding. Care must be taken to avoid nicking or damaging the wire during the forming operation as damage to the wire or wire surface may shorten thermocouple life. The wires should be spaced to permit free insertion into insulators.

A3.3 Gas or Arc Welding Types, E, J, K and T Thermocouples

In preparation for welding, the wires may be twisted as shown in Figure A-1 or positioned in a "V" as shown in Figure A-4. The twisted construction adds strength and facilitates welding.

For twisted AWG sizes 8 and 14, one inch of each wire should be prepared by removing any oxide or other surface finish with abrasive paper or by very careful filing or grinding. For twisted AWG 20, 24, and 28, the prepared length need be only one-half inch. The prepared ends are either twisted together to yield one and one-half turns as shown in Figure A-1 or positioned in a "V" as shown in Figure A-4 and then welded.

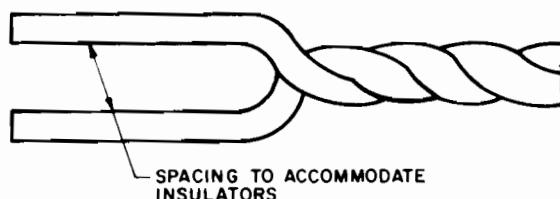


Figure A-1. Method of Twisting Wires for Gas and Electric Arc Welding

A3.4 Resistance Welding Types J and K Thermocouples

This method is recommended only for the 8 and 14 AWG wires. Approximately one-half inch of each wire should be sanded, in preparation for welding, with abrasive paper or by very careful filing or grinding.



Figure A-2. Method of Forming Metal Wires for Resistance Welding

*Trade Name

The sanded ends should be formed to produce longitudinal contact as shown in Figure A-2.

A3.5 Butt Resistance Welding Types E, J, and K Thermocouples

This method is recommended for 8 through 20 AWG wires and requires a good, commercially available, wire butt welder of suitable current capacity for the gage wire being welded. Approximately 0.5 inch of each wire should be sanded with abrasive paper in preparation for welding.

The sanded ends of the straight wires are butted together in the spring loaded butt welder jaws and spring pressure applied to the jaws. The weld is performed and the flash is removed by grinding. The wires are then bent as shown in Figure A-3.

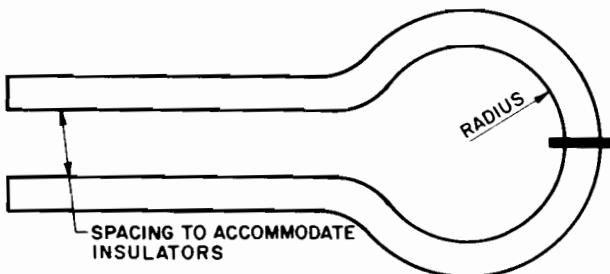


Figure A-3. Formed Butt Welded Thermocouple

A3.6 Resistance Welding Types B, R, and S Thermocouples

Extreme care should be taken to avoid cold working and contamination by oils, perspiration, dirt, etc. Sanding is not required.

The ends should be formed to produce a longitudinal contact of about one-eighth inch as shown in Figure A-2.

A3.7 Arc Welding Types B, R, and S Thermocouples

Extreme care should be taken to avoid cold working and contamination by oils, perspiration, dirt, etc. Sanding is not required.

The ends of the wires are positioned as shown in Figure A-4.

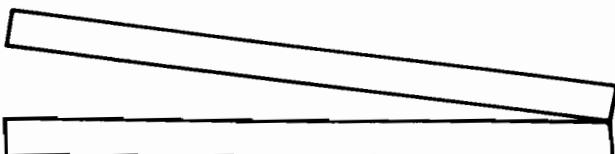


Figure A-4. Method of Forming Metal Wires for Electric Arc Welding

A3.8 Gas Welding

The character of the gas flame is the primary consideration of gas welding. A neutral flame as shown in Figure

A-5 is essential. The neutral flame is obtained by increasing the oxygen until the excess gas flame - shown dashed in Figure A-5 - just vanishes. Overshooting the vanishing point gives an oxidizing flame. AN OXIDIZING FLAME IS INJURIOUS AND SHOULD NEVER BE USED.

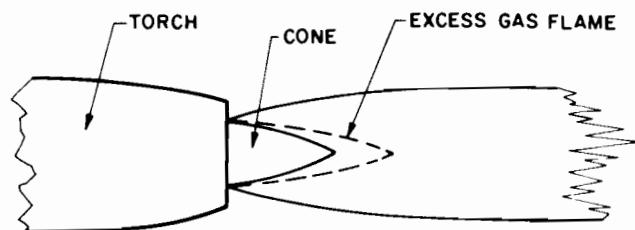


Figure A-5. Neutral Flame for Gas Welding

The smallest tip, that will readily heat the wires to fusion temperature, should be used. Continued heating at welding temperatures yields a poor weld.

Heat the ends of the twisted or "V" positioned wires to redness with the tip of the cone and plunge them into the flux. Reheat the wires to fusion temperature simultaneously, and rotate the weld to form a ball at the tip. Quench the welded junction in water to remove excess flux.

Attainment of the simultaneous fusion requires that the heating of the lower melting wire (see Table A-1) be delayed.

The junction should be examined with a low power magnifier for smoothness. A weld with a pitted surface must be rejected because it is burned (i.e. overheated to the point of incipient melting or intergranular oxidation). Repair of the weld is not feasible. An unsatisfactory weld must be cut off and the procedure repeated.

A3.9 Electric Arc Welding

Welded junctions may also be produced by an arc between two soft carbon electrodes or between one carbon electrode and the thermocouple wires as the second electrode. Only 8 and 14 AWG thermocouples should be used as the second electrode. Finer wires require two carbon electrodes. Direct current (dc) or alternating current (ac) may be used, but direct current is preferred. With direct current and a single carbon electrode, the thermocouple is connected to the positive lead. The ends of the twisted or "V" positioned wires are moistened, dipped into flux, and clamped upright in a vise with copper jaws. (Avoid surface damage in clamping.)

The two leads from the variable electric current source are connected either to the two carbon electrodes or one to the carbon electrode and the other to the vise clamping the thermocouple.

The size of the pure, soft carbon electrodes should be proportional to the wire size.

An arc is struck between the carbon electrodes or carbon electrode and thermocouple by momentary shorting. For

an 8 AWG thermocouple 30 to 45 volts is typical, and this value should be proportionately reduced for smaller sizes. With the single carbon electrode, a 1/16 inch arc gap minimizes oxidation and nitrogen absorption.

A brief welding cycle is best, since excessive current will result in burning. The bead should be small and solid. Bridges or gaps between the wires are weak and unsatisfactory. If an unsatisfactory weld results, it must be cut off and the procedure repeated.

A3.10 Electric Resistance Welding

Heating and fusion of the wires are accomplished by resistance heating of the wires and by contact resistance at their junction. This method is recommended only by Types B, R, and S, and the 8 and 14 AWG sizes of Types J and K. The junction of Figure A-2 is placed between the electrodes of a resistance welder. A suitable pressure-current-time cycle must be established by trial-and-error on identical scrap wires or by experience. Visual and destructive examination are required to establish

proper welding conditions. Excessive pressure will produce a good looking weld but only peripheral fusion. An unsatisfactory weld must be cut off and the procedure repeated.

A3.11 TIG and Plasma Arc Welding

The tungsten-inert gas (TIG) welding process and plasma-arc welding process are rapidly gaining in importance for welding thermocouple junctions. These welding processes use an inert gas envelope to protect the weld from oxidation in lieu of a flux. Welding using the TIG or plasma arc processes is done following the same routine as welding with one carbon electrode, except a flux is not used. The plasma arc has distinct advantages such as: no tungsten inclusions in the weld, extremely high temperatures in the plasma arc, a more controllable arc, and a constant pilot arc which can actually be used for fine welding, as well as a guide light to position the torch prior to starting the main arc, to name but a few. These processes are especially recommended for welding junctions in sheathed thermocouple wire. Procedures outlined above may also be used on types B, R, and S.

| Type of T/C* | Lower Melting | Silver Brazing | Welding | | | Resistance Welding | Plasma Arc or TIG | Butt Welding |
|--------------|---------------|----------------|-----------|-------------|--------------|--------------------|-------------------|--------------|
| | | | Flux** | Gas | Arc | | | |
| B | BN | N.R. | None | A3.1.2 | A.3.7 & A3.9 | A3.6 & A3.9 | A3.11 | - |
| E | EN | A3.1.1 | Fluorspar | A3.3 & A3.8 | A3.3 & A3.9 | N.R. | A3.11 | A3.5 |
| J | JN | A3.1.1 | Borox | A3.3 & A3.8 | A3.3 & A3.9 | A3.4 & A3.10 | A3.11 | A3.5 |
| K | KN | A3.1.1 | Fluorspar | A3.3 & A3.8 | A3.3 & A3.9 | A3.4 & A3.10 | A3.11 | A3.5 |
| R | RN | N.R. | None | A3.1.2 | A3.7 & A3.9 | A3.6 & A3.9 | A3.11 | - |
| S | SN | N.R. | None | A3.1.2 | A3.7 & A3.9 | A3.6 & A3.9 | A3.11 | - |
| T | TP | A3.1.1 | Borax | A3.3 & A3.8 | A3.3 & A3.9 | N.R. | A3.11 | N.R. |

N.R. -Not recommended

* See Table 1 of Standard for typical alloys

** Boric Acid also recommended for Types J, E, and K

NOTE: Numbers in body of table refer to paragraphs in Appendix A where the procedure for that type of joining is covered.

APPENDIX B

SHEATHED THERMOCOUPLE ELEMENT FABRICATION

B1. General

Sheathed thermocouple elements may be fabricated from commercially available sheathed thermocouple wire described in Chapter 5 of ASTM Special Technical Publication 470B. Fabricating such thermocouples successfully requires a higher degree of skill, special equipment and techniques, and virtually clean room conditions compared to fabricating customary bare wire thermocouples. Although this appendix is intended to assist those who desire to fabricate their own sheathed thermocouple elements, only general fabrication procedures are outlined below. A study of the literature on sheathed thermocouples and Chapter 5 of ASTM Special Technical Publication 470B, plus refinement of the procedures outlined below by practical experience are prerequisites to successful fabrication of sheathed thermocouple elements.

B2. Special Equipment

Although it is possible to remove the sheath by grinding and filing, special sheath stripping tools are commercially available and are highly recommended.

Welding is generally done using the Tungsten-Inert-Gas (TIG) process, and therefore a TIG welder is recommended. A plasma-arc welder is also excellent for this purpose.

It is often desirable to remove the insulant from around the thermocouple wires. Although this can be accomplished by tedious picking with a needle or other sharp instrument a miniature sandblaster is far superior.

A clean, dry and well lighted work area is essential to creating a finished element of high integrity.

Ovens capable of continuous operation at a minimum temperature of 200°F are suggested for storage of unsealed sheathed thermocouple wire and thermocouple elements during even short periods of delay where the compacted insulation might be exposed to air-borne moisture or other contaminants.

Special holding vises or fixtures are recommended for junctioning and capping sheathed thermocouple wire. The jaws may be made of commercial copper, and should be grooved to accept the various diameters of sheathed wire with which the fabricator plans to work.

B3. General Precautions

The crushed mineral oxide insulation in all sheathed thermocouple wire will rapidly absorb moisture. Thus the cable should be purchased with the ends closed by welding or suitably sealed in some other manner. Unsealed cable should be stored in an oven at 200°F or higher to reduce moisture pick-up.

All fixtures, vises and other tools brought into contact with the ceramic in the sheathed wire should be surgically clean to prevent contamination of the ceramic.

B4. Measuring Junction Fabrication

Exposed Junction (Wires not encased within sheath end closure.) The sheathed wire is cut to the desired length allowing for reference junction and measuring junction sheath removal. The sheath is removed from both ends as required, and the wires are cleaned by sandblasting or other suitable means. Wires are positioned and lightly clamped in a fixture such as a special copper jaws vise so that approximately 1/32 in. of wires are exposed above the vise jaws. The wires must touch one another at the surface of the jaws. The junction is fused by an electrical arc using the TIG welder with the ground lead connected to the vise jaws. The finished junction should look like Figure B-1. Both ends of the thermocouple element must be sealed with a suitable sealer to prevent contamination of the insulation, or the thermocouple element can be stored in an oven at 200°F until it is used.

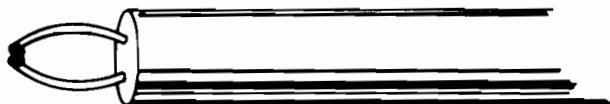


Figure B-1. Typical Exposed Junction

Grounded Junction (Wires encased within sheath end closure.) The sheathed wire is cut to the desired length allowing for the reference end sheath removal.

B4.1 On sheath diameters of 0.125 in. and smaller, the sheath and wires of the squared end can be simple welded over thus captivating both the sheath and the wires into the cap weld, creating a sound mechanical joint as well as electrical contact between the wires without diluting the cap weld metal with metal from the thermoelements. This weld is performed by positioning the squared end in a fixture such as copper jaws in a vise with closely fitting grooves for each size of sheathed wire. See Figure B-2.

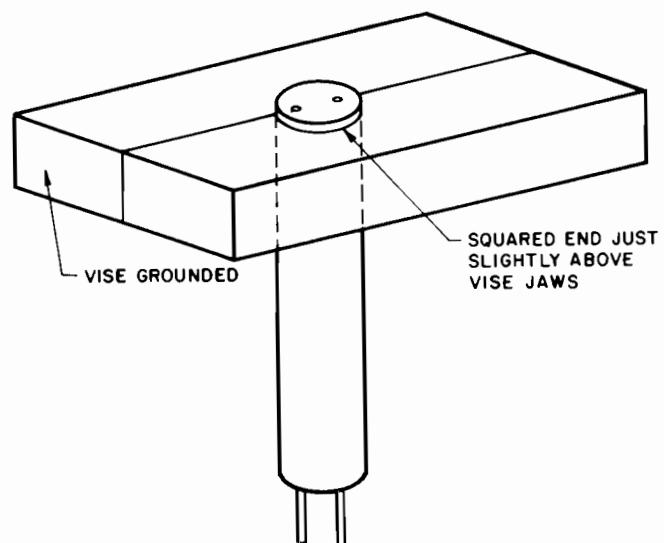


Figure B-2. Fixturing for Weldment

A TIG welder or plasma arc welder are best suited for welding, adding filler metal compatible with the sheath material as required.

B4.a Sheath diameters larger than 0.125 in. require slightly different methods. After squaring the end, a portion of the insulation is removed to a depth equal to approximately the inside diameter of the sheath. The reference junction end must have the sheath removed and the wires exposed to which the ground clamp from the welder is attached. The unit is positioned in the vise jaws in the same fashion as for forming the cap weld. An arc is struck on the wires thereby fusing them into a neat ball. The end is then capped as on smaller sheathed elements bringing the weld metal down into intimate contact with the welded wires, but not re-melting them. The general configuration of a grounded junction is shown in Figure B-3.



Figure B-3. Cutaway View of Grounded Junction

B4.3 Ungrounded Junction (Wires encased within but not touching sheath end closure.) The procedure for

producing this form of junction is not too unlike that of the grounded junction in sheathed wire larger than 0.125 in. O.D. After preparing the ends by squaring and removing the sheath, the insulation is removed on the measuring junction end to a level which will allow the wires to be welded together to the proper depth from the squared end. Care must be taken not to create a weld ball as large as the sheath I.D. which will ground the wires to the sheath and defeat the purpose of this type of junction. After the wires are joined, an insulation powder equivalent to that within the sheath is packed tightly around the welded wires and out flush to the squared end of the sheath. Capping is then done as before. Figure B-4 is typical of an Ungrounded Junction

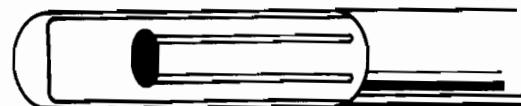


Figure B-4. Cutaway View of Ungrounded Junction

B4.4 The hygroscopic nature of most compacted insulations demands extreme care to avoid moisture pickup. It is very important to seal all ends where insulation is exposed as quickly and completely as possible.

APPENDIX C

THERMOCOUPLES AND THERMOCOUPLE EXTENSION WIRES - SELECTION, ASSEMBLY, AND INSTALLATION

C.1. Scope and Purpose

This section gives general information on the selection, assembly, and installation of commonly used thermocouples and associated thermocouple extension wires for specific applications.

C.2. Types and Uses

There are seven thermocouple types now in general use. The material designations are shown in C-1. The positive element of each couple is listed first.

Each of these types has individual characteristics that are desirable for some applications and unsuitable for others. In addition to the usual insulated forms all couples are available as compacted ceramic insulated thermocouples (See Section 2.2.8, page 14.)

Type T may be used in a vacuum, inert, oxidizing or reducing atmosphere. It commonly is used for sub-zero temperatures and has an upper temperature limit of 370°C (700°F) for wires at least 0.064 in. (1.63 mm) in diameter, in conventional closed-end protecting tubes. Its copper positive element is preferred to the iron positive

element of the Type J type for sub-zero use because of its superior corrosion resistance in moist atmospheres.

Type J may be used in a vacuum, inert, oxidizing, or reducing atmosphere. With elements of at least 0.128 in. (3.25 mm) in diameter, in conventional closed-end protecting tubes, it has an upper temperature limit of 760°C (1400°F). At high temperatures it should not be used in certain hydrogen containing atmospheres due to possible embrittling effects on the iron element. While this couple is occasionally used for sub-zero temperature measurements, the possible rusting or embrittlement of the iron under these conditions is at times undesirable.

Type E may be used in a vacuum, inert, oxidizing atmosphere and for temperatures up to 870°C (1600°F) for element wires at least 0.128 in. (3.25 mm) in diameter in closed-end protecting tubes. At sub-zero temperatures, the couple is not subject to corrosion. This thermocouple has the highest EMF output of any standard metal thermocouple.

Type K nominally is used to an upper temperature limit of 1260°C (2300°F) for wires at least 0.128 in. (3.25 mm) in diameter in conventional closed-end protecting tubes. It should be used either in inert or oxidizing

atmospheres. It has a short life in atmospheres that are marginally oxidizing, alternately oxidizing and reducing, or reducing atmospheres, particularly in the temperature range of 820°C to 1010°C (1500°F to 1850°F). An oxidizing atmosphere inside the protecting tube may be obtained by providing adequate ventilating. The use of a

sufficiently large protecting tube and an open head will be of material assistance. Type K thermocouples should not be used for accurate temperature measurements below 480°C (900°F) after prolonged exposure above 760°C (1400°F).

TABLE C-1
THERMOCOUPLE TYPES

| Type | Thermocouple Element | Thermocouple Wire Materials* |
|------|----------------------|---|
| B | BP BN | Platinum - 30% rhodium Platinum - 6% rhodium |
| E | EP EN | Nickel Chromium Copper Nickel |
| J | JP JN | Iron Copper Nickel |
| K | KP KN | Nickel Chromium Nickel Aluminum Silicon |
| R | RP RN | Platinum - 13% rhodium Platinum |
| S | SP SN | Platinum - 10% rhodium Platinum |
| T | TP TN | Copper Copper Nickel |

* These thermocouple materials are defined by their EMF characteristics. Alloy compositions may vary from lot to lot.

Types R and S may be used for temperatures up to 1480°C (2700°F) and Type B to 1700°C (3100°F) for wires at least 0.020 in. (0.51 mm) in diameter in conventional closed-end protecting tubes. These thermocouples are easily contaminated and should always be used in a protecting tube. The protecting tube also should be non-metallic and silica free, since the thermocouple can be contaminated by metallic vapors, reduced oxides, or other impurities at high temperatures. These elements may be used in inert or oxidizing atmospheres and for short periods of time in a vacuum - longer periods of time in vacuum if, for example, gas tight ceramic tubes or metal sheaths are used. They should not be used in a reducing atmosphere. Type S thermocouples are frequently used for calibration or checking since this type is one of the primary standards.

C3. Assembly

The fabrication of thermocouples requires special techniques as described in Appendix A. If the equipment and skill required to fabricate thermocouples properly are not available, the user should purchase fabricated thermocouples, since improper techniques can result in significant errors in temperature measurements.

Wire for making thermocouples preferably should be purchased in matched pairs in order to insure accuracy within standard limits of error of Section 3. However, positive and negative wires for types E, K, and T thermocouples, purchased at different times or from different suppliers, can be combined interchangeably. Wires to special limits of error given in Section 3 are obtained by selection and always should be purchased in matched pairs.

It is essential that the thermocouple have the same calibration as the instrument with which it is to be used.

Hard-fired ceramic insulators are used on most bare thermocouple elements. Insulators are available in single, double or multi-bore and a variety of shapes, sizes and lengths.

For types B, R, and S thermocouples it is recommended that insulators be of aluminum oxide and be of one piece, full length construction, to provide maximum protection from contamination. The insulator should also be light in weight or the assembly designed to minimize mechanical stresses on the noble metal wire.

For base metal thermocouples, insulation of braided glass or other fabric is sometimes used. Such materials should not be used with noble metal elements, as they will contaminate the thermocouple. Thermocouples may be made from insulated thermocouple wire, provided the insulation is suitable for the exposure temperature and intended service and will not contaminate the thermocouple or environment.

Protecting tubes are used for most thermocouple installations to prevent contamination of the thermocouple and provide mechanical protection and support. The minimum diameter of the protecting tube must be such as to accommodate the thermocouple element. However, larger diameter tubes are often required for (a) strength, (b) to permit insertion of a checking thermocouple alongside the service thermocouple and (c) to provide an adequate diameter to length ratio to assist in maintaining an oxidizing atmosphere for type K or E thermocouples. One half, three fourths, and one inch pipe size tubes are commonly used.

The length of the protecting tube (and thermocouple element) should be such as to place the measuring junction of the thermocouple well into the medium, the temperature of which is to be measured. A minimum immersion length of 8 to 10 tube diameters is recommended in order to minimize conduction errors.

Protection tubes must be internally clean and free of sulphur bearing compounds, oil, oxides, and sulphur-bearing compounds.

A wide range of metal and ceramic protecting tubes is available. Depending upon the application, the protecting tube should have some or all of the following properties:

1. Mechanical strength to withstand pressure and resist sagging at high temperatures.
2. Temperature resistance to withstand the temperature being measured; thermal shock resistance so that sudden temperature changes will not damage the tube.
3. Corrosion resistance to avoid chemical action with the medium in which the tube is immersed.
4. Erosion resistance.
5. Low porosity at operating temperature. This is especially true of protecting tubes installed in furnaces since furnace gases are generally damaging to thermocouples.

Some of the common protection tube materials and the maximum operating temperatures are given in Table C2.

TABLE C-2
PROTECTION TUBES

| Protecting Tube Materials | Maximum Operation Temperature | |
|------------------------------|-------------------------------|--------|
| | Deg. C | Deg. F |
| Carbon Steel | 540 | 1000 |
| Wrought Iron | 700 | 1300 |
| Cast Iron | 700 | 1300 |
| 304 Stainless Steel | 870 | 1600 |
| 316 Stainless Steel | 870 | 1600 |
| 446 Stainless Steel | 980 | 1800 |
| Nickel | 980 | 1800 |
| 75 Nickel - 15 Chromium-Iron | 1150 | 2100 |
| Porcelain | 1650 | 3000* |
| Silicon Carbide | 1650 | 3000 |
| Alumina-Silica | 1650 | 3000* |
| Aluminum Oxide | 1750 | 3200* |

* Horizontal tubes should receive additional support above 1480°C (2700°F)

In addition to the conventional thermocouple construction described in this Appendix, sheathed, compacted, ceramic insulated thermocouple material is in common use. This material consists of one or more thermoelements encased in ceramic insulating material (usually magnesium oxide) which is firmly compacted within a metallic sheath. The nature of this construction is such as to require special fabricating techniques, and it is therefore recommended that the user purchase such thermocouples completely fabricated.

1. Sheathed, compacted thermocouple material can be obtained in (a) all calibration types, (b) a variety of sheath diameters ranging from 0.010 in. to 0.500 in. diameter and (c) a choice of sheath materials to withstand specific environments. Insulating materials, other than magnesium oxide, are also available.
2. The choice of sheath diameter will depend upon such factors as life expectancy, speed of response requirements and space limitations. Large diameter material will provide longer life but will have a slower response. For a more complete discussion of sheathed, compacted, ceramic insulated thermocouples, the user is referred to ASTM "Manual on the Use of Thermocouples in Temperature Measurement," STP 470B.

C4. Installation Considerations for Thermocouples

C4.1 In installing thermocouples it must be always borne in mind that the EMF produced depends upon the difference in temperature between the measuring and reference junctions. With a fixed or known reference junction, the thermocouple thermometer is capable only of indicating the temperature attained by its measuring junction. It is thus necessary in a particular process to insure that the measuring junction is at the same temperature within the accuracy desired as the medium to be measured. The errors discussed elsewhere in this standard are negligible compared with those that may result by not making the installation in such a manner that the measuring junction attains the temperature to be measured.

The measuring junction temperature actually obtained in an installation is a result of the net heat supplied to that junction by the conventional modes of heat transfer; i.e., conduction, convection and radiation. Where protection tubes or wells are necessary in an installation, the problem is only aggravated. Among the many factors which influence the measuring junction temperature of a particular installation are:

1. Temperature of the surroundings
2. Velocity and properties of the fluid
3. Emissivity of the exposed surface
4. Thermal conductivity of thermocouple and well materials
5. Ratio of heat-transfer areas

Under installation conditions where the surrounding (duct

wall) temperatures are appreciably different from the fluid temperatures in the case of gases, heat exchange will take place by the mechanism of radiation by the thermocouple and its surroundings. In addition, heat will flow from or to the thermocouple by the mechanism of conduction, and heat will be transferred by convection. Depending upon whether the surrounding temperatures are higher or lower than the gas temperature, the thermocouple will indicate higher or lower temperature. Where great differences in temperature exist between the gas and the surroundings, publications on heat transfer should be consulted treating the thermocouple thermometer as a "thin-rod" type of problem.

The thermocouple thermometer should be located in a position where the mass velocity is as high as practicable to assure good heat transfer by convection; however, if the velocity is in excess of 300 ft/sec. then a specially-designed stagnation-type probe should be used. When a thermocouple must be installed in a location where the velocity is very low, then it may be necessary to induce a flow of gases past the junction. Several aspirating types of pyrometers are available for this purpose.

C4.2 A thermocouple connection head is recommended to provide positive connections between the thermocouple and the extension wire. The head also permits easy replacement of the thermocouple.

C4.3 The protecting tube should extend beyond the outer surface of the vessel furnace or processing equipment so that the temperature of the connection head approximates the ambient atmospheric temperature. This is especially true for Types B, R, and S thermocouples using compensating extension wires. The connection head temperature should never exceed the temperature limits given in Section 3 for thermocouple extension wires.

C4.4 After all the steps outlined above have been carried out, the actual installation of a thermocouple still requires some care. Both the thermocouple and the extension wire should be cleaned before fastening in the terminal block to assure good electrical contacts. Color-coded insulation identifies the positive and negative elements of the extension wire. It is necessary to have the thermocouple wire tagged or otherwise identified as to polarity. The following information can be used to determine polarity in the field.

C4.4.1 For extension wire having insulation color-coded in accordance with Section 1, *the negative wire insulation is always colored red.*

C4.4.2 For Type E, the negative wire is silver in appearance. It has a lower resistance in ohms/foot than the positive element for the same size wire.

C4.4.3 For Type J, the positive element is frequently rusty and is magnetic. It has a lower resistance in ohms/foot for the same size wire.

C4.4.4 For Type K, the negative element is slightly magnetic. It has a lower resistance in ohms/foot for the same size wire.

C4.4.5 For Type R and S, the negative wire is softer than the positive wire. The negative wire also has a lower resistance in ohms/foot for the same size wire.

C4.4.6 For Type T, the positive wire is copper-colored and the negative wire is silver in appearance. The positive wire has lower resistance in ohms/foot for the same size wire.

C4.5 Bottoming of the thermocouple in the protecting tube is often practiced to improve the response to temperature change. Bottoming consists of having the thermocouple junction pressed tightly against the end or "bottom" of the protecting tube. However, bottoming

may ground the thermocouple which, with some types of installations causes difficulties.

C4.6 It must be borne in mind that zero error is unattainable. In addition to the instrument error, the thermocouple and the extension wire will introduce errors. In Section 3 are tabulated the initial tolerances that can be expected in new materials. The installed components may deteriorate with use, and methods of checking the installation are given in Appendix D.

C5 Installation of Extension Wires

C5.1 Types of extension wires for use with various types of thermocouples are listed in Table C3.

TABLE C-3
TYPES OF EXTENSION WIRE

| Thermocouple Type | Extension Wire | Extension Wire Elements* |
|-------------------|----------------|--|
| B | BX | BPX Copper BNX Copper |
| E | EX | EPX Nickel Chromium ENX Copper Nickel |
| J | JX | JPX Iron JNX Copper Nickel |
| K | KX | KPX Nickel Chromium KNX Nickel Aluminum |
| R or S | SX | SPX Copper SNX Copper Nickel Alloy |
| T | TX | TPX Copper TNX Copper Nickel |

*These thermocouple materials are defined by their EMF characteristics. Alloy compositions may vary from lot to lot.

C5.2 Potentiometer type instruments are not critical as to extension wire resistance. However, single wires and pairs smaller than 16-gage are not recommended for use in conduit, as they do not have sufficient strength for pulling. Twenty-gage and smaller wire may be used when assembled in suitable reinforced bundles to provide pulling strength. Where extension wire smaller than 16-gage is required, insulated thermocouple wire, instead of extension wire, may be used. The total resistance of the extension wire is important when used with galvanometer millivoltmeter-type instruments. Some millivoltmeters require a definite resistance in the extension wire.

Many of the more recent millivoltmeters are made with a high internal resistance. The extension wire used with these instruments does not have to be calibrated but the total resistance should be kept to approximately the value given on the instrument scale. Therefore, it is usually

necessary to use a large size wire. Sizes 14- and 16-gage are recommended.

The resistance of electronic instruments is often high enough to place no restraint on the resistance of the extension wire.

Due to the fast response of such instruments, fluctuations due to noise may require noise suppression techniques.

C5.3 The insulation used on extension wires may be divided into four general classifications: waterproof, moisture resistant, heat resistant, and radiation resistant. Materials used for insulating extension wire are selected to perform a variety of functions. These include: physical protection, bonding, mechanical separation, and electrical insulation.

In a permanently dry location these functions can be performed by non-conducting substances such as cotton, glass, asbestos fibers, paper tapes, and ceramic beads. Where moisture may be present, more or less impervious barriers are required. These may be enamel coatings, asphalt or wax impregnations, plastics, rubber or lead sheaths. Where heat resistance is necessary, glass, asbestos fibers, and ceramics may be used. Where the extension wire may be exposed to varying degrees of heat and moisture, a combination of two or more of these materials may give a satisfactory insulation.

C5.4 Thermocouple extension wire should always be installed in the best manner to protect it from excessive heat, moisture, and mechanical damage. Wherever practicable it should be installed in conduit so that it is not subjected to excessive flexing or bending, which might change the thermoelectric characteristics.

The layout and arrangement of the conduits for a thermocouple system should be given considerable thought. Long radius bends should be used instead of elbows where possible; cold working of thermocouple elements can introduce inhomogeneity, and pulling of the extension wire through a number of elbows could work the wires unnecessarily.

While it is generally desirable to keep the length of extension wire as short as possible, it is often possible to have one conduit serve a number of thermocouples. The extent of conduit fill is not as significant with thermocouples as with power wiring because the lower current causes lower heating. (Conduit fill is the ratio between the cross-sectional area of all of the wires and the area of the conduit.)

For minimum error the extension wire should be run from the thermocouple connection head to the instrument terminal or reference junction in one continuous length; junction boxes may introduce errors and can be avoided by design of the conduit system with the proper pull points. When splices are unavoidable, they should be made by compressing the two wires to be joined with a mechanical device to obtain intimate contact. No other electrical wires should ever be run in the same conduit with extension wires.

When installing extension wire underground, always use waterproof insulation. Running extension wires parallel to or in close proximity to power lines should be avoided. When any connections are made, polarity must be strictly observed.

APPENDIX D

THERMOCOUPLES-CHECKING PROCEDURES

D1. General

New thermocouples, thermocouple materials, and thermocouple extension wire are controlled by the supplier to fit a published temperature-EMF table or curve within stated tolerance limits. Thermocouple extension wire normally retains its original characteristics when used within recommended temperature limits, but thermocouples, which are exposed to high temperatures in various atmospheres, may change characteristics. To avoid the continued use of thermocouples with excessive deviations from the original characteristic due to such exposure or contamination, it is good practice to check the thermocouples at regular intervals.

New material, not previously exposed to temperature gradients, can be checked by techniques described in ASTM E-220-72.

D2. Scope and Purpose

Recommendations and suggestions are given below for simple and ordinarily adequate procedures for checking installed thermocouples. These are not intended to be completely self-sufficient, however, and usually it will be advantageous to consult more detailed treatments as well.

“Temperature Measurement,” Part 3 of the Performance Test Codes Supplement on Instruments and Apparatus, PTC 19.3, published by the American Society of Mechanical Engineers, gives thorough coverage to the use

and calibration of thermocouples. Calibrating procedures for new thermocouple materials are given in NBS Special Publication 300, Volume II, “Precision Measurement and Calibration-Temperature”. This describes various testing methods and the precautions which must be observed in order to attain various degrees of accuracy. In particular, it describes in detail the methods developed and used at the National Bureau of Standards. Further information is available in E220-72, “Calibration of Thermocouples by Comparison Techniques,” published by the American Society for Testing and Materials.

D3. Procedure

D3.1 The checking of installed thermocouples is complicated by the thermo-electric non-uniformity resulting from contamination or deterioration of the elements. The unheated terminals of the used thermocouple will normally be like new - the actual junction, contaminated or deteriorated, and the intermediate material affected to various degrees.

The output of a contaminated or deteriorated thermocouple will not be determined solely by the temperature of the heated junction, as with a new homogeneous thermocouple, but also by the temperature gradient between the measuring and reference ends and the pattern of contamination and deterioration in the temperature gradient zone. FOR THIS REASON A USED THERMOCOUPLE SHOULD NOT BE REMOVED FROM ITS INSTALLED LOCATION AND PLACED IN A CALIBRATING FURNACE FOR CHECKING. IT IS HIGH-

LY IMPROBABLE THAT THE TEMPERATURE GRADIENTS IN THE TWO INSTALLATIONS WILL BE THE SAME.

A used thermocouple must be checked in its normal installed location. The purpose of checking an installed thermocouple is not to determine its temperature-EMF characteristics, but to determine the temperature error in actual service. This can most readily be done by temporarily installing a new or checking thermocouple along side the service thermocouple, or in its place, and comparing the readings. If the installed thermocouple is used to measure a wide range of temperatures, it should be checked at more than one temperature within the range of its use. Testing of a thermocouple at a single temperature yields some information, but it is not safe to assume that the changes in the EMF of the couple are proportional to the temperature or to the EMF.

D3.2 Where the protecting tube is large enough, a checking thermocouple may be inserted beside the service thermocouple. It is recommended that a separate checking instrument be used with the checking thermocouple to permit checking of the service instrument, as well as of the service thermocouple.

Where the protecting tube is not large enough to permit the insertion of an additional thermocouple, it is necessary to remove the service thermocouple and to replace it with a checking thermocouple. When this method is used, it is essential that stable temperature conditions be maintained. In general, the higher temperature or more contaminating the atmosphere, the more frequently checks should be made.

D3.3 Large temperature gradients can exist in commonly used furnaces and other devices, and points physically close together may be at surprisingly different temperatures. The procedure of checking a thermocouple installation by means of a checking thermocouple inserted through a furnace door or otherwise installed in a different part of the apparatus from the service thermocouple is not recommended, since the thermocouple reading may fail to agree and yet both may be correct.

D3.4 Checking thermocouples or secondary standards should be homogeneous and uncontaminated. Any new thermocouple may be used, but it should be checked against a primary standard and tagged with its deviation from the standard curve. If a user does not have the equipment and technique for doing this, calibrated and tagged thermocouples are available. The National Bureau of Standards or other standardizing laboratories will furnish a report on the temperature-EMF characteristics of a submitted thermocouple.

D3.5 The accuracy of a checking thermocouple or secondary standard will become questionable after use. Noble metal thermocouples may normally be relied upon for a considerable period of use, provided that the checking temperatures have not been avoided. Base metal thermocouples used for checking purposes should be checked frequently.

NOTE: Base metal couples should not be used for checking purposes below 480°C (900°F), if they are exposed between checks at temperatures above 760°C (1400°F).

BIBLIOGRAPHY

ASTM Standard E220, "Standard Method for Calibration of Thermocouples by Comparison Techniques", American Society for Testing and Materials

ASTM Special Technical Publication STP-470B, "Manual on the Use of Thermocouples in Temperature Measurement", American Society for Testing and Materials

ASTM Standard E-563, "Standard Recommended Practice for Preparation and Use of Freezing Point Reference Baths", American Society for Testing and Materials

NBS Monograph 124, "Reference Tables for Low Temperature Thermocouples", National Bureau of Standards

NBS Monograph 125, "Thermocouple Reference Tables Based on the IPTS-68 including Supplement 1", National Bureau of Standards

NBS Special Publication 300, Volume II, "Precision Measurement and Calibration Temperature", 1968.

NBS SP 373, "Bibliograph of Temperature Measurement", National Bureau of Standards, Jan. 1953-Dec. 1969

Roeser, W.F. and S.T. Lonberger, "Methods of Testing Thermocouples and Thermocouple Materials", Circular 590, National Bureau of Standards, 1956

"Temperature Measurement", Performance Test Codes Supplement on Instruments and Apparatus, Part 3. PTC 19.3-1974, American Society of Mechanical Engineers, 1974.

"Thermocouple Thermometers", PMC Standard No. 8-10-1963, SAMA-PMC Section Inc.

See also standards of ASTM Committee E-20 on Temperature Measurement.

ISA STANDARDS AND RECOMMENDED PRACTICES

| | | |
|--|--|--|
| S61.1 — Industrial Computer System FORTRAN Procedures for Executive Functions, Process Input-Output, and Bit Manipulation ANSI/ISA-1977 1976, 11 pp. | RP74.01 — Application and Installation of Continuous-Belt Weighbridge Scales 1984, 20 pp. | S75.16 — Face-to-Face Dimensions for Flanged Globe-Style Control Valve Bodies (ANSI Classes 900, 1500, and 2500) ANSI/ISA-1987 1986, 8 pp. |
| S61.2 — Industrial Computer System FORTRAN Procedures for File Access and the Control of File Contentions ANSI/ISA-1978 1978, 7 pp. | S75.01 — Flow Equations for Sizing Control Valves (R 1985) ANSI/ISA-1985 1985, 28 pp. | S75.17 — Control Valve Aerodynamic Noise Prediction ANSI/ISA-1991 1991, 20 pp. |
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